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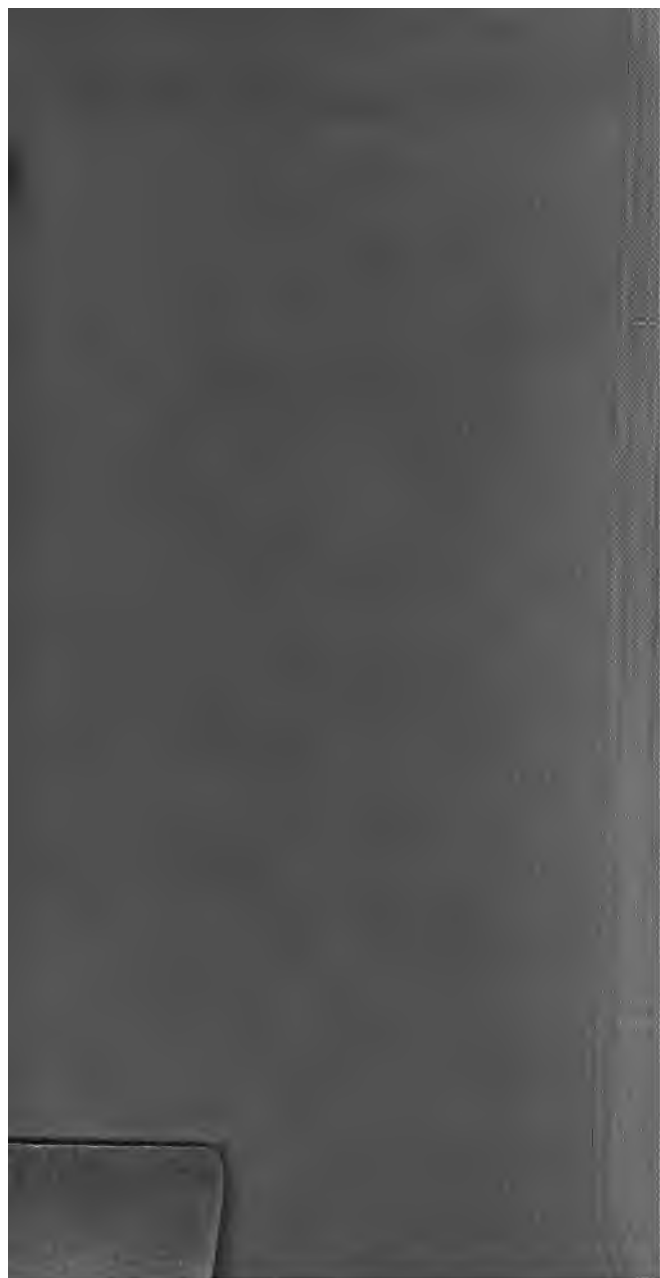
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THE
PRINCIPLES
OF
CHEMISTRY:

PREPARED FOR THE USE OF
SCHOOLS, ACADEMIES, AND COLLEGES.

By DANIEL B. SMITH.

SECOND EDITION,
REVISED AND ADAPTED TO THE PRESENT CONDITION OF THE SCIENCE.

PHILADELPHIA:
URIAH HUNT, 101 MARKET STREET.

1842.



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PREFACE

TO THE FIRST EDITION.

DR. WHATELY, in his excellent Treatise on Rhetoric, has remarked that it is "impossible to lay down precise rules as to the degree of conciseness which is, on each occasion that may arise, allowable and desirable; but to an author who is, in his expression of any sentiment, wavering between the demands of perspicuity and of energy, and doubting whether the phrase which has the most forcible brevity, will be readily taken in, it may be recommended to use both expressions; first to expand the sense, sufficiently to be clearly understood, and then to contract it into the most compendious and striking form." "The hearers," he adds, "will be struck by the forcibleness of the sense which they will have been prepared to comprehend; they will *understand* the longer expression, and remember the shorter."

The principle involved in these very just remarks has guided the compiler in preparing the following pages. At the stage in the progress of academical study in which chemistry is appropriately introduced, it is necessary to begin to accustom the student to instruction by means of lectures. The power of close and continued attention to spoken discourse, is an invaluable acquisition to the youthful mind, and one of the highest attainments of a well disciplined intellect. There seems, indeed, to be no other method by which adequate instruction in the higher departments of intellectual pursuits can be imparted, than by a judicious blending together of oral and written instruction, combining a full commentary in the form of lectures, with a text containing a clear and concise exposition of facts and principles. It is to this mode of instruction that the remarks

we have quoted are applicable. The student will be struck by the forcibleness of the sentence which he will have been prepared to comprehend; and he will thus understand, as well as remember, the shorter and concise expression of the principles that have been previously illustrated at length. To give full effect to this system of instruction, it will be necessary to require of the student that he take notes of the lecture, or prepare an abstract thereof, and undergo an examination respecting such illustrations and experiments as are not contained in the text book.

The study of chemistry appears to the compiler to be peculiarly adapted to familiarize a student to this mode of instruction. The science is one of details, so numerous and intricate, that the text book which should attempt to include them all, would be too cumbersome and overloaded with detail to admit of being thoroughly learned. A selection of facts must therefore be made, and it seems most judicious to select such as are familiar and fundamental, or adapted to the illustration of principles, and to leave all beyond this to the particular taste and views of the teacher. A text book, prepared according to this plan, appears to the compiler to be better adapted than any other for the purposes of academical instruction; for the great object of education, is not to convey a knowledge of the greatest possible number of individual facts, but to discipline the intellectual faculties, and prepare the youthful mind for the comprehension of those general laws of nature, the knowledge of which chiefly distinguishes the civilized from the savage state—the cultivated and intellectual from the rude and uninformed individual.

Those who may adopt the compiler's views, and use this little work as a text book, will find, in the excellent treatises of Drs. Silliman and Hare, a variety and multiplicity of experiments, which will render the preparation of lectures for illustrating the text, an easy task.

Haverford, 11mo., 14th, 1837.

PREFACE

TO THE

S E C O N D E D I T I O N .

THE changes which have taken place in the science, since the first edition of these Elements, have rendered it necessary to rewrite the greater part, so that it is almost a new work. The reader will see that the compiler is greatly indebted to Graham, Kane, Daniell, and Liebig, for the new matter which has been incorporated into the present edition. A treatise, so humble in its pretensions, will scarcely attract criticism; yet the author would observe, in defence of the arrangement he has adopted, that it has one advantage of practical utility to the teacher and the student, namely, that of spreading the experimental illustrations pretty equally over the whole course of instruction, an advantage which will, he thinks, be appreciated by competent judges.

HAVERFORD, 9mo. 2d, 1842.



THE ELEMENTS OF CHEMISTRY.

INTRODUCTION.

1. **CHEMISTRY** is that department of **Physics** which investigates the changes that take place in bodies, in consequence of their attraction or affinity for each other.

2. The physical properties which depend on the powers of Gravitation, Cohesion, Heat, Light, and Electricity, form the subjects of the several departments of natural philosophy. It is by these, and their other sensible properties, that we ascertain the identity or diversity of bodies. Chemical changes more or less affect these properties, and some account of them seems therefore necessary as an introduction to the science of Chemistry.

CHAPTER I.

GRAVITATION AND COHESION.

3. *Attraction of Gravitation.* — Light bodies which float on water, attract each other at perceptible distances. The force of this attraction varies as the mass; and the velocity with which they ap-

proach each other depends on that force, so that if one of the bodies be twice the size of the other, the smaller body will move twice as fast as the larger. This velocity increases as their distance lessens, and the rate at which it increases is inversely as the square of the distance.

4. All bodies whatever attract each other by this law. This force, which is called the attraction of gravitation, pervades the universe, and binds together the various systems of suns and planets. It is in virtue of this force, that all bodies tend to the earth in straight lines perpendicular to its surface.

5. What we call the *weight* of bodies, is this tendency to the earth, measured by the force required to counteract it. It is important to have a fixed standard with which to compare the weight of other bodies. Water has been adopted for this purpose, as the standard for solids and liquids. This relative weight of bodies is called their *specific gravity*; in expressing it, the weight of water is taken as unity; so that when we state the specific gravity of a body to be 2 or 3, we mean that it is two or three times as heavy as an equal bulk of water. The specific gravity of a body is ascertained by weighing it in air, and afterwards in water. The loss of weight is the weight of an equal bulk of water; and this divided into the weight in air, gives the relative weight or the specific gravity of the body.

The weight of a cubic foot of water is nearly 997 avoirdupois ounces; so that if the specific gravity of water be taken at 1000, the specific gravity of a body will express very nearly the weight in ounces of a cubic foot of its mass. The weight of the atmosphere at the temperature of 60° F., and under a barometric pressure of 30 inches, is the standard, with which the weight of all other gases at the same temperature and under the same pressure is compared. In order to compare the two standards, we must

divide the specific gravity of gases by 815, which will give their weight as compared with that of water.

6. *Attraction of Cohesion.*—It is in virtue of this attraction, that the particles of bodies cohere in masses. Fluidity and solidity, with its various degrees of elasticity, tenacity, ductility, toughness, softness, friability and hardness, are various modified effects of this cohesive force. The tendency of this attraction being to draw the particles of bodies to each other, it would, if left to itself, bring them into actual contact. But it is certain that no two particles of matter really touch each other, for there is no body which does not contract in all its dimensions by cold. It seems manifest, therefore, that every material particle must exert a repulsive as well as an attractive force. If the former decrease more rapidly than the latter as the distance increases, it may be powerful enough to prevent the particles from coming into contact, and yet give place at a certain distance to the latter. The equilibrium of these opposite forces will explain fluidity, and the toughness and adhesiveness of many substances; for if it were the only cause of cohesion, a sliding motion among the particles would always be possible when the two forces were in equilibrium.

7. In order to explain the immoveability of the particles in most solids, we must resort to an additional supposition. If we conceive every particle of matter to be like a small magnet possessing opposite points or poles, each of which repels the same point or pole in every other particle, while it attracts the opposite, it is clear that the arrangement of the particles will be determined by the axes of polarity; and that firm solids of a definite figure, will be the result of arranging the opposite poles so as to connect with each other.

8. *Crystallization.*—Bodies often cohere in masses

of no determinate shape, which are called *amorphous*. But by allowing them to pass slowly from a fluid to a solid state, most bodies assume regular or crystalline forms. These crystals are generally bounded by polished plane surfaces. The same body in crystallizing, often assumes a great variety of forms, all of which are found to be modifications of one original or primitive crystal. The laws which regulate this deviation from the form common to them all, admit of mathematical investigation, and are the subject of the science of Crystallography. A knowledge of them is so far important to the chemist, as to require a brief explanation in this place.

9. All those crystals which may be derived from one another, and which can be deduced from the same primitive crystalline form, are said to belong to the same crystallographic system. What is meant, may be illustrated by the changes of which the cube is susceptible. If we suppose the solid angles of the cube to be cut off or truncated by planes at right angles to its solid diagonal, we shall change its figure into an octohedron, the six solid angles of which are in the centres of the six plane faces of the cube. It is obvious that this process of truncation may stop at any stage of its progress, so that the resulting figure shall preserve the form either of a cube or an octohedron with its solid angles truncated. It is also obvious that the process may be reversed, and the cube formed from the octohedron by the truncation of its solid angles.

10. If lines be conceived to be drawn from the opposite solid angles of the octohedron, there will be three equal lines or axes passing through the centre of the crystal. These lines will coincide with those drawn through the centre of the opposite faces of the cube. The cube and the octohedron are therefore said to possess the same crystallographic axes; that is to say, the axes passing through the centre of the

crystal from opposite solid angles, or the centres of opposite faces, coincide.

11. If the edges of the cube be truncated by planes parallel to the respective diagonal planes of the cube, the resulting figure will be the regular rhomboidal dodecahedron, the six acute angles of which are in the centre of the six faces of the cube. This figure is, therefore, said to possess the same crystallographic axes as the cube and octohedron. If the edges of the cube be bevelled, that is to say, cut off by two planes equally inclined, instead of one, the resulting figure will be a cube with four low pyramids on each face, and which, from its general resemblance to that solid, is called the *tetra hexahedron*. By variously bevelling the edges and angles of these crystals, we obtain as many various crystalline forms, all of which are said to belong to the same system; that is to say, they possess the same crystallographic axes.

12. A clearer notion of the nature of crystals may be gained by conceiving what must be the structure of the cube. The cube may be conceived to be formed in the following manner. Eight particles can be arranged so as to form a minute cube, each face of which contains two rows of particles. This can be increased to any size by the successive addition of layers of particles each consisting of a row more than the layer on which it is imposed. If, when it has gained a certain size, when, for example, it consists of seventeen rows of particles on each face, the law of increase be changed and each successive layer consist of two rows less than the one beneath, a square pyramid eight rows in height will be built up, on each face of the cube, and the adjacent sides will be in the same plane, so as to form the regular rhomboidal dodecahedron. If the law of decrement, as it is termed, be more rapid than two rows for every additional layer, the adja-

cent sides of the pyramid will not be in the same plane, and the 24-sided figure already spoken of as the *tetra hexahedron* will be formed. We can easily frame the law of decrement by which the regular octohedron can be conceived to be formed from the cube, and vice versa.

13. It has already been said that in order to explain the hardness of firm solids, the existence of opposite poles of attraction and repulsion in the particles of matter must be assumed. Polarities of this kind must also be taken for granted in any theory of crystallization, and if they exist, it is evident that there will be lines or planes of stronger and weaker attraction, and that the crystal will more easily split in the latter than in the former direction. Such is found to be the case.

All the various crystalline forms which the same substance is capable of assuming, are, as has been said, modifications of *one* primitive form, and all such crystals are found to split with plane polished surfaces in planes parallel to the planes of this primitive form, and they admit of cleavage in no other direction. We can hence ascertain by means of their cleavage, the primitive form of those crystals, of which only the secondary or derived forms are found in nature.

The cube or hexahedron, the regular octohedron, and rhomboidal dodecahedron, have the same crystallographic axes and belong to the same crystallographic system.

14. There are seven primary forms of crystals, incapable of being reduced to each other according to the known laws of crystallography, giving rise to all the various secondary forms that occur in nature, and characterized by the number, length, and position, of their crystallographic axes.

The first of these is the cube which has three equal rectangular axes. It constitutes the class *Mono-metrica*.

The second is the square prism, which has all the axes rectangular; the two horizontal ones equal, and the vertical either greater or less than the others. It forms the class *Dimetrica*.

The third is the right rectangular prism which has all the axes unequal and rectangular. It forms the class *Trimetrica*.

The fourth is the right rhombic prism, the lateral axes of which, intersect each other obliquely, while they are both at right angles to the vertical axis. It is the class *Monoclinata*.

The fifth is the *oblique rectangular prism*, which has its lateral axes at right angles to each other while both of them are oblique to the vertical axis. It is the class *Diclinata*.

The sixth is the oblique rhomboidal prism, which has all its three crystallographic axes oblique to each other. It is the class *Triclinata*.

The seventh is the regular rhombohedron, which is a solid whose faces are six equal rhombs. Each face has therefore two acute and two obtuse angles opposite to each other. The solid angles of the rhombohedron are thus formed either by three acute or three obtuse plane angles, or by two obtuse and one acute, or by one obtuse and two acute plane angles. The crystal is said to be in its proper position when the axis passing through the solid angles bounded by similar plane angles is perpendicular to the horizon. The other six angles will then be symmetrically ranged round the vertical axis, and the lines uniting them through the centre of the solid are called the lateral axes. This figure has therefore four equal crystallographic axes. It is the class *Tetrazona*.

The first of these systems is the only one of which the forms are all interchangeable and the axes invariable. The proportions and inclinations of the crystalline axes in the other systems vary indefinitely, and as they do not change in the same mineral, the

measurement of the angles of crystals, in order to ascertain the dimensions of their primary form, becomes one of the most valuable means of determining the species of crystalline minerals.

15. The laws by which the edges and solid angles are truncated, are such that the resulting figure possesses either the same axes as the primary, or axes which are in a definite multiple ratio to them. By the truncation of the various prisms are formed the several varieties of the octohedron. The hexagonal prism is the result of the truncation of the lateral angles of the rhombohedron by vertical planes.

These explanations seem necessary in order to prepare the student to understand the value of a similarity in crystalline forms as an indication of similarity in the composition of bodies.

16. *Repulsion*. —The repulsive force, which is the antagonist power of cohesion, is evidently the principle, or matter, or force, which is the cause of the sensation of heat. To this unknown cause the name *Caloric* has been given. The examination of its nature and properties constitutes a distinct department of science, and it is with its relations to the force of cohesion that we are mainly concerned in chemistry.

Those general properties of bodies which depend less on the nature of their component parts than on their state of aggregation, will be found to be principally the results of these two forces of cohesion and caloric.

CHAPTER II.

CALORIC.

17. It is by means of our sensations of warmth and cold that we acquire our first knowledge of the existence of such an agent as *caloric*. Our fur-

ther acquaintance with its properties is derived from observing the changes which bodies undergo in circumstances which affect us with either of these sensations. Whatever caloric be, it is evident that it tends to diffuse itself among all the bodies within its influence, for cold bodies brought near to warm ones always become warm. This is evident to a sentient being from his feelings, and it is proved by the changes which bodies thereby undergo. We must therefore examine in the first place, what those changes are, and in the second, how they are produced. The most striking are those which take place in their state of aggregation, and in their dimensions. Water is changed by cold into a firm solid, and it boils and is converted into vapour when heated. Observation proves that these changes take place at constant degrees of heat, and they therefore furnish us with fixed points beyond, and between which, we can determine other effects of caloric.

18. *Expansion*—If a bar of iron be cooled to the temperature of melting ice, and a piece of it, precisely three feet long, be then cut off, and if the piece be immersed in boiling water, it will be found, by accurate measurement, that it has gained the 23d part of an inch in length. By the same change of temperature, a glass rod of equal dimensions would be lengthened the 35th, a rod of brass the 15th, and one of lead the 10th part of an inch.

By exposing these bars to a still greater degree of heat, they will be found to expand still more, and in the same relative order. If, after having thus heated them, we again immerse them in melting ice, we shall find that they have recovered their original length.

If, instead of a bar, we try the experiment on a *cube* of either of these substances, we shall find that it has expanded equally in all its dimensions.

These experiments prove that solid bodies expand

by heat, and contract by cold; and that different bodies do not expand equally by the same increase of temperature.

19. The following table exhibits the expansion of several substances when heated from the freezing to the boiling point of water.

English flint glass, - - -	$\frac{1}{1248}$	of its length.
Glass tube without lead, -	$\frac{1}{1118}$	"
Platinum, - - - - -	$\frac{1}{1167}$	"
Untempered steel, - - -	$\frac{1}{937}$	"
Tempered steel, - - - -	$\frac{1}{807}$	"
Gold, - - - - -	$\frac{1}{803}$	"
Copper, - - - - -	$\frac{1}{881}$	"
Brass, - - - - -	$\frac{1}{833}$	"
Silver, - - - - -	$\frac{1}{824}$	"
English tin, - - - - -	$\frac{1}{463}$	"
Lead, - - - - -	$\frac{1}{381}$	"

Three times the expansion in length will be a very close approximation to the total increase in bulk of the substance.

20. The *pyrometer* is an instrument for rendering sensible the expansion of solid bodies by different degrees of heat. A rod of metal, or any other substance, the expansion of which is to be tried, is laid upon two supports on the base of the instrument. One end touches the short arm of an upright lever, the long arm of which is connected with the short arm of an index. The other end of the rod is adjusted, and kept from moving, by means of a screw. The levers are so adjusted that the expansion of the bar is multiplied 100 times by the index, and if the rod be ten inches in length, and the degrees of the scale are an inch long, a motion of the tenth of a degree by the index will measure an expansion of the rod equal to 1000th part of its length. The heat is applied to the rod by means of a small spirit lamp. When it is wished to ascertain the expansion between the temperature of freezing and boiling wa-

ter, the rod is passed through water-tight collars in the ends of a long metallic box containing water, to which heat is applied.

Breguet's pyrometer is a very delicate instrument for measuring small changes of temperature, and consists of a narrow metallic slip, about $\frac{1}{160}$ of an inch thick, composed of silver and platinum soldered together, and coiled in a cylindrical form. The top of this spiral tube is suspended by a cross-arm, and the bottom carries, in a horizontal position, a very delicate golden needle, which traverses as an index on a graduated circular plate; a steel stud rises in the centre of the tube to prevent its oscillating from a central position. If the silver be on the outside of the spiral, the influence of increased temperature will increase the curvature, and move the appended needle in the direction of the coil, while the action of cold will relax the coil, and move the needle in an opposite direction.

21. The cohesive attraction lessens as the distance between the particles increases; it therefore follows that bodies expand more by equal increments of heat at high, than at low temperatures. This is ascertained by experiment to be the case. Hallstrom found that a bar of iron of which the length was 1. at the freezing point of water, lengthened to 1.001446 when heated to its boiling point. Dividing the difference of temperature into five equal intervals, he found the expansion for the

First interval to be	-	-	.000211
Second	"	-	.000242
Third	"	-	.000281
Fourth	"	-	.000329
Fifth	"	-	.000383

It also follows that liquids expand more by heat than their respective solids, and it is found that liquids expand generally more than solids.

If several glass tubes of equal diameter, open at

one end, and terminating at the other in bulbs of equal size, be partially filled, one with alcohol, one with olive oil, another with water, and another with mercury, at the common temperature, and be then placed in hot water, it will be seen that the fluids all rise in the tubes, and that the alcohol expands most and the mercury least. It is therefore, evident that they expand more than glass, for if the glass expanded as much as the contained liquid, there would be no relative change of bulk.

If the interval between freezing and boiling water be equally divided, and the expansion of these liquids in the warmer interval be taken at 15, their expansion during the colder half will be as follows: mercury 14, olive oil 13.4, alcohol 10.9, and water 4.7. This experiment proves that liquids as well as solids expand more by equal increments of heat at high, than at low temperatures.

22. It follows from what has been said, that as there is no cohesive force to overcome in gases, they must all be expanded alike by equal increments of the repulsive force. This is verified by experiment. It appears from the researches of Gay Lussac, that 100 cubic inches of atmospheric air, in being heated from the freezing to the boiling point of water, expand to 137.5 cubic inches. All the gases which have been subjected to the same trials, expand by the same quantity; and it is ascertained that the rate of expansion is uniform between the freezing, and the boiling point of mercury.

This uniform or nearly uniform expansion of most bodies by equal increments of heat, enables us to construct the *thermometer*, an instrument, by which we measure those changes of heat and cold designated by the word temperature, with an accuracy which our own feelings are incapable of attaining.

As atmospheric air expands equally for equal in-

crements of heat, it forms a perfectly accurate measure of the change of temperature. The construction of the air thermometer is extremely simple: a glass tube, of an uniform bore, is to be selected for the purpose, and one end of it is blown into a spherical ball, while its other extremity is left open. After expelling a small quantity of air by heating the ball gently, the open end of the tube is plunged into coloured water, and a portion of the liquid is forced up into the tube by the pressure of the atmosphere as the air within the ball contracts. In this case, it indicates changes of temperature with extreme delicacy, and the alternate contraction and expansion of the confined air, may be measured by the alternate ascent and descent of the coloured water in the stem. This instrument is, however, affected by the varying pressure of the atmosphere upon the liquid in the vessel, as well as by heat; and the expansion and contraction of the confined air are so great that it can only be used for small variations of temperature. The air thermometer is, therefore, seldom employed, except in a modified form, called the *differential thermometer*. This instrument consists of two thin glass bulbs at the extremity of a tube, bent twice at right angles. Both bulbs contain air; but the greater part of the tube is filled with coloured sulphuric acid, so that, when the air in both bulbs is at the same temperature, the fluid in both stems is at the same height. The slightest difference between the temperature of the two balls will cause the liquid to rise in the tube next to the ball, the temperature of which, is relatively lower. A graduated scale is affixed to one of the tubes, by means of which the changes of this instrument can be compared with those of a common thermometer.

23. The expansion of mercury between its freezing and boiling point furnishes us with the most accurate and convenient measure of these changes.

The mercurial thermometer is constructed by nearly filling with mercury, a glass tube of uniform bore, having a bulb at one end. The mercury is then heated till it fills the tube, or boiled till the atmospheric air within the tube is replaced by mercurial vapour, and the tube is then hermetically sealed. The tube is attached to an ivory or metallic plate upon which the scale of temperature is marked. In order to graduate the instrument, it is dipped into melting ice or snow, and the point to which the mercury sinks is marked on the scale. Another mark is made opposite to the place in the tube to which the mercury rises when the instrument is dipped in boiling water. The space between these two points has been variously divided into degrees by different philosophers.

Reaumur, whose thermometer is used in France, called the freezing point 0° , and the boiling point 80° . Celsius, a Swedish naturalist, called the former 0° , and the latter 100° . Four degrees of the former, are therefore, equivalent to five of the latter, which is often called the centigrade thermometer.

In Great Britain and America, the graduation contrived by a Dutch instrument maker, named Fahrenheit, is in general use. Fahrenheit conceived that the cold produced by a mixture of equal parts of snow and salt, was the greatest that could be obtained. He, therefore, in graduating his instrument, made a third mark at the point to which the mercury sunk in such a mixture, and called this 0° , or zero. He divided the space between the freezing and the boiling points of water into 180° , and, by continuing the graduation downwards, he found that there were thirty-two of these degrees between the freezing point and his zero. He, therefore, called the former 32° , and the boiling point 212° . In order to reduce degrees of Reaumur to those of Fahrenheit, multiply them by $2\frac{1}{2}$, and to the product add 32, when

the degrees are above, and subtract it, when they are below 0° . To find the degrees of Fahrenheit equivalent to those of Celsius, multiply by $\frac{9}{5}$, and add or subtract 32 as before.

Although mercury expands more at high, than at low temperatures, yet as the glass which contains it has the same law of increased expansion, the one compensates for the other, and the scale may be extended without material error, both upwards and downwards from the boiling and freezing points of water. Mercury boils at 662° F. (350° C.) on the scale so extended, and becomes solid at -39° F. ($-39\frac{1}{2}^{\circ}$ C.), which is the greatest range of any thermometric scale. Thermometers may be constructed of alcohol, which remains fluid at the lowest temperature to which it has hitherto been exposed; but this liquid boils at a heat below the boiling point of water, so that mercury is by far the most useful liquid for thermometers. The absolute expansion of mercury, in passing from the freezing to the boiling point of water, is $\frac{100}{88880}$; which gives the expansion for each degree of Fahrenheit $\frac{1}{88880}$, and for each degree of the centigrade $\frac{1}{88880}$.

24. For measuring high degrees of heat, various modifications of the Pyrometer have been invented. The most accurate of these is Daniell's pyrometer, in which the temperature is measured by the expansion of a platinum rod. It consists of two parts, a register and a scale. The former is a bar of black lead earthenware, in which is drilled a hole, into which a cylindrical rod of platinum, of nearly the same diameter, is introduced so as to rest against the solid end of the hole. Upon the outer end of the rod, rests a cylindrical piece of porcelain, which is firmly secured in its place. The scale consists of two rules of brass fitted to the end of the register, by means of which, the actual expansion of the rod is multiplied and measured on the arc of a circle, in the

same manner as in the common pyrometer. The total expansion of the black lead case is so small that it may be neglected without any sensible error, and the whole register is infusible in any heat that has hitherto been obtained in a furnace. When the register is exposed to a great heat, the expansion of the metallic rod pushes forward the cylinder of porcelain, which remains in the position which is thus given to it. After the instrument has cooled, it is applied to the scale, which measures, with minute accuracy, the expansion the rod has undergone in consequence of the heat into which it has been exposed.

25. There is a remarkable exception to this law of expansion by heat. Certain fluids as they approach the freezing point, cease to contract, and then begin, and continue to expand as the temperature is lowered. Water is an instance of this anomaly; for its point of greatest density is at the temperature of 38.97° (3.87° C.), and it then begins to expand at the same rate by which it contracted, so that its bulk at 32° (0°) is equal to that which it possesses at 45.94° (7.74° C.). This expansive force of water, as it approaches congelation, is an agent of prodigious power. In one experiment it was sufficient to burst a strong brass globe, the cavity of which was an inch in diameter; and it was estimated to be equal, in this case, to an actual pressure of 27,720 pounds. The most probable supposition which has been made of the cause of this phenomenon, is, that, as they approach the freezing temperature, the particles of water begin to assume a certain crystalline arrangement, in virtue of which they occupy a greater space and expand. A beneficial consequence of this law is, that ice is always lighter than water, and that the water at the bottom of fresh water lakes and rivers is never frozen.

Other liquids, besides water, obey this remarkable

law. Melted iron and bismuth expand in becoming solid, while mercury undergoes a sudden contraction.

26. *Capacity for Heat.*—If equal quantities of any fluid, unequally heated, be mixed together, the temperature of the mixture will be the exact mean of the temperatures of the separate quantities before they were mingled. For example, a pound of water at 160° , being mixed with a pound of water at 40° , the temperature of the mixture will be 100° , proving that the quantity of caloric which a pound of water parts with in being lowered 60° , is precisely that required to raise an equal quantity of water the same number of degrees.

27. If, however, we mix a pound of water at 160° with a pound of spermaceti oil at 40° , the temperature of the mixture will not be, as before, 100° , which is the mean, but 120° , and if the oil is 160° and the water 40° , the temperature of the mixture will be 80° . If again a pound of water at 160° be mixed with a pound of mercury at 40° , the temperature of the mixture will be 155° , and if the water be 40° , and the mercury 160° , the temperature of the mixture will be 45° . From these experiments we learn that bodies are unequally heated by the same quantities of heat. The caloric which will raise the temperature of a pound of water from 40° to 50° , will raise a pound of oil from 40° to 60° , and a pound of mercury from 40° to 270° .

28. The same fact may be proved by means of the quantity of ice at 32° , which different substances will melt in being lowered a certain number of degrees. The instrument for performing these experiments is called a calorimeter. The substance to be experimented on, is placed within a vessel containing ice, which is kept at 32° , by being surrounded by melting ice in an outer vessel. The melting of the ice in the inner vessel is owing solely to the heat

communicated from the heated body within, and the water it forms is carefully drained off and weighed. In this manner it has been ascertained that a pound of water, in cooling a certain number of degrees, will melt 23 times as much ice, and a pound of spermaceti oil, $11\frac{1}{2}$ times as much as a pound of mercury, under the same circumstances. It is also ascertained, that other different substances melt different quantities of ice, under similar circumstances.

29. It is therefore conceived that the absolute quantity of caloric, which is contained in bodies, must vary, and that each substance, in passing from lower to higher temperatures, combines with or absorbs greater or less quantities of caloric, according to its own law of affinity or absorption. Hence, if we take the relative quantities of heat requisite to raise different bodies the same number of degrees of the thermometer, as the nearest measure we can obtain of the actual quantities thus absorbed, water may be regarded as having 23 times as great a power of absorption, or as it is termed *capacity for heat*, as mercury, and twice as great a capacity as oil.

We have no means of ascertaining in any case the absolute quantity of caloric in combination with bodies, and the closest approximation we can make to it, is this determination of the *specific heat*, as it is termed; that is, the relative quantities, absorbed or given out by bodies in undergoing equal changes of temperature.

30. If this power of absorbing caloric, whether it be termed affinity or capacity for heat, or specific heat, be diminished in any body, it is evident that a portion of the combined caloric will be disengaged, or set free, and that the temperature will rise. If, on the contrary, it be increased, the body will absorb caloric and the temperature will fall. Gases are of all bodies those whose capacity for heat is most easily affected. Condensation decreases and rarefaction

increases their specific heat, and hence the former raises and the latter lowers their temperature. For example: if air be suddenly compressed in a condensing syringe, the heat disengaged in consequence of the sudden reduction of its specific heat, will be sufficient to set fire to tinder, and a flash of light will at the same moment be visible. Again, a thermometer placed in the receiver of an air pump, uniformly falls during the process, and in proportion to the progress of exhaustion, and rises again upon the admission of the air. This fact has been applied to the explanation of the intense cold, experienced in the upper and rarefied portions of the atmosphere.

31. The specific heat of a body varies with its state of aggregation. The only substance of which the specific heat is known in these various states is water; that of ice being .9; of water 1.; and of steam .847.

32. The following table exhibits the specific heat of several substances, chiefly determined by Regnault, (Kane, p. 101.)

Water,	1.000	Silver,	.057
Carbon,	.241	Tin,	.056
Sulphur,	.202	Mercury,	.033
Iron,	.114	Platinum,	.032
Zinc,	.095	Gold,	.032
Copper,	.095	Lead,	.031

33. *Heat of Fluidity.*—An increase of its sensible temperature is the surest indication we possess of the passage of caloric into a body. By reason of the tendency of caloric to an equilibrium, the sensible temperature of cold bodies, that are placed within the influence of warmer ones, is steadily and equally increased.

34. There are two remarkable exceptions to this law. If ice, wax, and lead, each of the same temperature, say 0°F. (-17.77°C.) be exposed alike to a heat equal to that of boiling mercury, they will all,

for a time, exhibit a steady increase of temperature. If the bulb of a thermometer be inserted in a hole in the middle of each, so as to mark its temperature, the following changes will take place. When the thermometer inserted in the ice rises to 32° F. (0° C.) it will become stationary, although those placed in the wax and lead continue steadily to rise.

The thermometer inserted in the ice remains stationary at 32° , until all the ice is melted, and then again rises as before. In like manner the thermometer placed in the wax, continues to rise, till it reaches the temperature of 136° F. (57.77° C.) when the wax begins to melt. It remains stationary until the wax is all melted, and then again rises as before. The same temporary suspension of the rise of the thermometer, inserted in the lead, occurs, when it reaches the temperature of 612° F. (322.2° C.) the fusing point of that metal.

35. Although from its known properties, we may be sure that caloric has, during all this time, been passing into the ice, the wax, and the lead, there has been an interval, that, namely, of their passing into the fluid state, during which they gave no indication by the thermometer of an increase of temperature. The heat, therefore, which it received during this period, was employed in melting the body, and not in raising the sensible temperature. The unavoidable inference is, that during the process of fusion a portion of caloric has combined with the body, in such a way, that its presence is not indicated by the thermometer.

36. The caloric which is thus absorbed by solids in becoming fluid, is given out by fluids in becoming solid. Although the freezing point of water is 32° F. (0° C.) it may, by being kept perfectly still, be cooled to 22° F. (-5.55° C.) If it be then suddenly agitated, the temperature of the whole mass will be raised to 32° F., and a portion, which Dr. Thompson

ascertained to be $\frac{1}{14}$ of the whole quantity, will at the same time be congealed. The caloric given out in the act of congelation by that portion of the water which has become frozen, has therefore been sufficient to raise fourteen times its quantity of water, ten degrees of the thermometer; or, in other words, it is sufficient to raise its own bulk of water, 140 degrees of the thermometer.

37. That this is the quantity of caloric the ice had absorbed in becoming fluid, is proved by the following experiments. If equal weights of water and ice, both indicating 32° , be exposed alike to the temperature of boiling water, it will be found as before, that a thermometer placed in the ice will not begin to rise till it is all melted, at which time that immersed in the water will indicate 172° , proving that 140° of heat had become *latent*, as it is termed, in the fusion of the ice. If, again, a pound of ice at 32° , be immersed in a pound of water at 172° , the ice will be melted, and the temperature of the whole will be 32° , which satisfactorily shows that in becoming fluid, the ice had absorbed and rendered insensible to the thermometer, the caloric which an equal quantity of water had given out in falling 140° .

38. Irvine determined the quantity of heat rendered latent in certain bodies during the process of liquefaction, by noting the rise of the thermometer when it was immersed during the same period, and under the same circumstances, in an equal quantity of the same body in a fluid state. The results are given in the second column of the following table, while the numbers in the third are the latent heat, as compared with that of water.

Water,	140°	1000.
Sulphur,	143.68	207.3
Zinc,	493.	334.5
Tin,	500.	200.
Bismuth,	550.	113.

39. This absorption of caloric in the process of liquefaction, has been applied to the production of extreme degrees of cold. Solutions in water, and in certain acids, of various salts, are liquid at very low temperatures; and when they are formed by mixing their elements in a solid and finely divided state, the liquefaction takes place suddenly with so rapid an absorption of caloric from the surrounding bodies, as greatly to reduce the temperature. Thus a mixture of two parts by weight of snow, with one of common salt, reduces the thermometer to -5° F., and a mixture of two parts of snow with three of chloride of calcium, lowers the temperature from 32° F. to -50° F. To ensure success in these experiments, the salts must be newly crystallized and finely powdered, and the materials must be previously cooled in a freezing mixture.

40. *Vaporization*.—All bodies, as has been already observed, exist either in the solid, liquid, or aeriform state, according to the proportions of caloric with which they are combined. The same phenomenon that takes place in liquefying solids, namely, that of rendering latent a large and definite portion of caloric, is essential to the conversion of liquids into gases. This conversion takes place even at very low temperatures. The upper or superficial stratum, not only of liquids, but of certain solids, appears to possess the power of absorbing, and rendering latent, the caloric which exists in a free state in the surrounding medium, and thus of imperceptibly and continually assuming the gaseous form. The number of superficial particles which admit of being thus rendered gaseous, depends jointly upon the sensible temperature and the affinity of the body for caloric.

41. The density of the vapour of any given body which is capable of existing at a given temperature, is constant quantity. This may be readily proved by taking two glass tubes closed at one end, filling

them with recently boiled mercury, and inverting them over mercury. They will both indicate the same pressure of the atmosphere by the equal height of the mercurial column. If a small quantity of water be introduced into the upper part of one of the tubes, and its temperature be gradually raised from 32° F. (0° C.) to 212° F. (100° C.), it will be found that the pressure of the vapour which exists at the respective temperatures will be as stated below, being measured by the depression of the column of mercury in the tube that contains the water, below the height that it stands in the other tube.

32°	0.2	inches	100°	1.86	inches
50	0.375	"	150	7.42	"
60	0.524	"	212	30.—	"

42. These pressures are found to be constant at the same temperatures, and to be altogether independent of the presence of any other gas; or, in other words, the quantity of the vapour of water capable of existing at a given temperature, is dependent solely upon the temperature. This is ascertained to hold respecting all other liquids upon which experiments have been tried, and is therefore regarded as an universal law.

43. As only a certain density of vapour can exist at a given temperature, evaporation goes on from the surface of a liquid until that density be attained. The rapidity with which it proceeds will therefore increase in proportion to the warmth and dryness of the air, and to the extent of surface. It is also increased by a current which continually brings new portions of air into contact with the surface of the liquid. Although the quantity of vapour capable of existing at a given temperature is altogether independent of the density of the atmosphere, this density greatly affects the rapidity of evaporation. In a vacuum water boils at 70° , and if means be taken to absorb the vapour as fast as it is formed,

the caloric abstracted from the water and rendered latent by the portion which is converted into vapour, will cause the remaining liquid to freeze. This may be shown by placing two shallow vessels, one containing sulphuric acid and the other water, under an exhausted receiver. The acid absorbs and removes the vapour as fast as it is formed, until at length the water is frozen.

44. Advantage has been taken of this law to separate two mixed liquids, by exposing them in *vacuo* to a substance which absorbs the vapour of one and not of the other. If a mixture of alcohol and water be placed in the upper vessel described above, and the receiver be exhausted, it will soon be filled with the vapour of both liquids at their maximum density. But if the lower vessel be filled with dry quick lime, the aqueous vapour will be absorbed as fast as it is formed, and thus a continual evaporation of the water will take place, until at length the alcohol, which does not evaporate, is left pure.

45. The *Cryophorus* of Dr. Wollaston, is an instrument for illustrating these laws. It is a glass tube, bent in a right angle at each extremity, and then terminating in a bulb. One of the bulbs is half filled with pure water, the air is entirely expelled, and the tube hermetically sealed. On placing the empty bulb in a freezing mixture, the vapour is condensed in it as fast as it is formed in the other bulb, the evaporation in which goes on so rapidly as to congeal the remaining water.

The pulse glass is a small instrument on a similar principle, for exhibiting the low temperature at which water boils in a vacuum.

46. It will be seen, by reference to the table on page 35, that at the boiling point of water the pressure of its vapour upon the surface of the liquid is equal to that of the atmosphere. The phenomenon of ebullition arises from this circumstance, and the

agitation of the liquid, which we call boiling, is caused by the rapid formation of bubbles of aqueous vapour throughout the body of the liquid; for until the elasticity of the vapour is equal to that of the atmosphere, it is only the superficial stratum of particles that is converted into gas, and the process of heating the fluid goes on without disturbance. As ebullition takes place whenever the elasticity of the vapour that is formed is sufficient to overcome the pressure of the atmosphere upon the surface of the liquid, its temperature must vary with that pressure. This is shown by placing a vessel of hot, but not boiling water under the receiver of an air pump, and exhausting the air. The water begins to boil as soon as the pressure upon its surface is less than the elasticity of the vapour.

47. By removing the pressure altogether, liquids in general, according to Robinson, boil at 140° F. (77.8° C.) lower than in the open air. The heat of the hand will boil water in the vacuum of the common pulse glass, and ether will boil in it at the temperature of freezing mercury. By increasing the pressure upon the surface, we increase the temperature of the boiling point of liquids. In the following table the first and third columns indicate the pressure, that of the atmosphere being unity, and the second and fourth the temperature at which water boils when exposed to it.

TABLE.

1	212°	5	307°
2	250.52	10	358.88
4	293.72	20	418.46
8	341.78	40	486.59
16	382.48	50	510.60

48. That liquids render caloric latent in becoming aeriform, is shown by the same proofs as in the liquefaction of solids. As solids cannot be heated

beyond their melting point, so liquids cannot be heated beyond their boiling point. All the additional heat that passes into the liquid is employed in converting it into vapour, the temperature of which is, notwithstanding, precisely that of the liquid itself.

If we condense a given weight of steam, by passing it in a spiral metallic tube (as the worm of a common still, for instance) through water, we shall find that it will heat about ten times its weight of water from 32° to 145° , that is, the quantity of caloric given out by aqueous vapour in being condensed, is sufficient to heat ten times its own weight of water 113 degrees, and it may therefore be stated to be 1212° . This is found to hold true at whatever temperature the steam is formed; that is, steam generated under the pressure of 50 atmospheres and indicating a temperature of 510.6° , gives out no more heat in condensing than an equal weight of steam formed at the common pressure, and indicating, therefore, the ordinary boiling point of 212° . But as the sensible temperature of the steam in the one case is 478° , and in the other 180° above 32° ; 478° of the heat communicated to the water in the former case, and 180° of that communicated in the latter, must be regarded as being furnished by the sensible heat of the steam, and the latent heat in the former case must therefore have been 652° , and in the latter 950° .

49. The same facts have been ascertained in respect to other vapours, and we thus arrive at the remarkable law that the sum of the sensible and latent heat of a vapour, at whatever temperature and under whatever pressure it is formed, is a constant quantity.

50. Excepting, then, that at the higher temperature more heat is lost from the apparatus by conduction and radiation, no more caloric is required to generate a given weight of vapour at 510° than at

212°, while the elasticity or value as a mechanical power, of the steam at 510°, is fifty times that of steam formed at the ordinary pressure.

51. The following table exhibits the boiling point of several liquids, the latent heat of their vapours, and the increase of volume of each fluid in becoming vapour.

	Sp. Gr.	Boiling point.	Latent heat of vapour.	Sp. Gr. of vapour.	Increase of volume.
Water	1.000	212°F.	1000°	.625	1689.
Alcohol	.813	173.5	457	1.601	493.5
Ether	.736	100.	312.9	2.581	212.18
Oil of Turpentine	.86	316.	183.8	4.764	192.15

52. When liquids which mingle in all proportions, as alcohol and water, are of unequal volatility, we can separate them by exposing the mixture to a temperature below that at which the least volatile boils, and collecting and condensing the vapour of the other. This process of distillation is chiefly used in obtaining alcohol from fermented liquors, and their essential oils from plants which have been previously macerated with water.

53. *Liquefaction of Gases.*—As the state in which bodies exist, is found to depend upon their temperature, it is evident that there must be a degree of cold in which all fluids become solid, and all gases fluid or solid; while on the other hand heat will liquefy or volatilize all solids. There are no solids which chemists have not been able to melt or volatilize; alcohol is the only substance, liquid at common temperatures, which has not been frozen. Many of the permanent gases have been liquefied by cold and pressure, and one of them, namely, carbonic acid, has been solidified. This liquefaction of the gases was first performed by Faraday, by disengaging them from their combinations, under a pressure, and in a space that did not allow of their assuming the gaseous form. For this purpose the materials for producing

the gas are put into a strong glass tube which is afterwards hermetically sealed, and bent in the middle in an obtuse angle. The gas is generated by the application of heat, if necessary, and when the pressure becomes sufficiently great, is condensed into a liquid form and collects in the free end of the tube. The great elasticity of the condensed gas, (equal in some cases to a pressure of 50 atmospheres,) renders some of these experiments extremely dangerous.

54. *Penetration of Gases.*—The mechanical action of gaseous fluids upon each other is regulated by peculiar laws. When two liquids of unequal density are placed in the same vessel, they do not mingle, unless in consequence of chemical affinity, but the heavier remains at the bottom. If, however, two vessels, communicating by their necks be placed the one above the other, and the one be filled with hydrogen gas, and the other with carbonic acid gas, which is twenty-two times heavier than hydrogen and has no affinity for it, the gases will be found after a short interval to be equally diffused throughout the whole space. This experiment proves that the presence of a substratum of gas twenty-two times heavier than itself, is no obstacle to the diffusion of the hydrogen through the lower flask as completely as if it had been empty. When the two gases are in contact, the particles of each gas insinuate themselves between those of the other until they are perfectly mingled. It has been, therefore, inferred by Dalton, that the particles of gas, although highly repulsive of each other, do not repel those of a different kind. This does not seem, however, to be a necessary inference; and the mutual penetration of gases is probably a consequence of that disturbance of their equilibrium, which must take place when the two vessels are made to communicate. We know that the particles of other bodies freely penetrate between those of water, and when it is recollected that the

particles of aqueous vapour are twelve times more distant from each other than those of the liquid, it is evident that the slightest disturbance in the equilibrium of a gas so constituted, must be propagated throughout its whole volume, and that it can only be restored by the equal diffusion of the similar particles. This, in the case of gases, whose corpuscles differ in respect to magnitude and weight, must produce the mutual penetration which is characteristic of elastic fluids.

55. If the two vessels in the above experiment be separated by a plug of plaister of paris, it will not prevent the mutual penetration of the gases. If a bottle containing hydrogen gas have its mouth closed by a sheet of bladder, or Indian rubber, the hydrogen will escape through it, and the external air will at the same time pass into the bottle: yet the hydrogen will pass through so much more rapidly than the atmospheric air that the membrane will be forced in, and will finally be torn by the external pressure.

Experiments have proved that the velocity, with which this diffusion takes place, is inversely as the square root of the specific gravity of the gas, and that if the vessel be surrounded by a vacuum the several gases will pass through the porous stopper of plaister in times proportioned to the same law. By the following table it will be seen that in the time in which 100 measures (the diffusion volume) of atmospheric air, pass through a porous plug, 383 volumes of hydrogen, 130 of ammonia, &c. will escape.

	<i>Sp. Gr.</i>	<i>Sp. Gr.</i>	<i>Diffusion volume.</i>
Hydrogen,	.0688	.2623	383
Ammonia,	.5898	.7681	130
Air,	1.—	1.—	100
Carbonic Acid,	1.5239	1.2345	81
Chlorine,	2.4700	1.5716	64

56. This law does not hold when the gases are in

contact with moist membranes or Indian rubber; for in these cases the gases which are most easily liquefied are transmitted in the greatest quantity, and it seems necessary to suppose that they are condensed by contact with the membrane and that they pass through in the fluid state.

57. In perfectly elastic fluids, the density varies as the pressure. The gas which under a pressure of one pound on the square inch occupies two cubic feet, will be compressed into half the space by double the pressure. This law is known by the name of Mariotte's law. There is reason to believe, that under very great pressure, and at temperatures much above the boiling point of their respective fluids, it does not hold good. Under very powerful pressure fluids may be made to assume the gaseous form, in a space but little greater than their bulk when liquid. Ether becomes a gas at 320° in twice the space it before occupied; alcohol at 404° becomes gaseous in a space only three times greater than its liquid volume; and water at 773° is a gas with four times its fluid bulk. In all these cases the elastic force of the vapour is less than the theory of elastic fluids would lead us to suppose.

As a general rule gases expand far more than liquids, yet carbonic acid, which is only known to us in its liquid form under very great pressure, expands one per cent. of its bulk for every degree of Fahrenheit, which is four times the rate of the expansion of air. These facts render it probable that under extreme circumstances of heat and pressure, there are states intermediate between a liquid and a perfectly elastic gas, analogous to the viscosity of tenacious fluids, and the flexibility of soft solids.

58. *Incandescence*.—When a solid substance, such as iron, is heated to a certain temperature, it begins to emit light, in conjunction with heat. Luminous hot bodies are said to be *incandescent*; and the tem-

perature at which solids become incandescent in the dark is between 600° and 700° F. They do not become luminous in broad day light till about 1000° F. The colour of incandescent bodies varies with the temperature. The lowest degree is an obscure red, which becomes more and more vivid till it acquires a full red glow, which gradually becomes white, shining with increased brilliancy as the heat augments. Liquids and gases become incandescent when strongly heated, but a very high temperature is required to render a gas luminous, higher than is sufficient for heating a solid body even to whiteness. The most intense incandescence known, is that produced by placing a fragment of lime, or of the other earths, in the jet of flame from an oxyhydrogen blow pipe. So powerful is the light thus produced by a piece of lime no larger than a filbert, that it has cast a shadow at the distance of a quarter of a mile.

59. *Flame*.—The different kinds of flame are incandescent gas. That this is the case is evident from the examination of the flame of an ordinary lamp. If the combustible used be alcohol, a flame of great heating power but of a feeble light is emitted, because the products of the combustion are gaseous. In the oil lamp the lower part of the flame emits a pale blue light, for there the combustion is at once perfect. Higher up, where the combustible material is in excess, the flame is of a brilliant yellow, passing into an intense white light, and surrounded by a pale yellow flame. The dark interior of the flame is the column of inflammable vapour which rises from the wick, and of which only the external particles are in contact with the air so as to take fire. The flame is therefore a hollow cone, of which the paler external portion contains only gaseous particles, while the white light of the interior stratum is owing to the

solid particles of carbon, which are heated to brilliant incandescence before they are completely burned.

60. *Transmission of Heat.*—If we apply the hand to a number of different bodies exposed in the same situation, we shall find them to indicate very unequal degrees of warmth, while a thermometer will probably exhibit the same temperature in them all.

If we dip into a vessel of boiling water the ends of wooden, leaden, and copper rods, of equal length and thickness, we shall find the copper rod to become hot sooner than that of lead, and this much sooner than the rod of wood.

These simple experiments acquaint us with the fact that caloric passes with different degrees of velocity through bodies; which are hence divided into conductors and non-conductors of heat. The metals belong to the former, and wood, glass, and charcoal, to the latter class. Fine down, silk, wool, and cotton, are the slowest conductors of heat among solid bodies.

The following table, by Despretz, shows the relative conducting power of the substances mentioned:—

Gold,	1000	Tin,	303.9
Silver,	973	Lead,	179.6
Copper,	898.2	Marble,	23.6
Platinum,	381	Porcelain,	12.2
Iron,	374.3	Clay,	11.4
Zinc,	363		

61. What has been said of the constitution of liquids, and the expansive effect of heat, has prepared the student for understanding the manner in which fluids are heated. When the heat is applied at the bottom of a vessel containing any fluid, the mass first heated expands, and, thus becoming

specifically lighter than those around them, rise to the surface. They are replaced by other cold particles, and thus the whole mass of the fluid is brought in succession to the part where the heat is applied, and heated there. This circulation of particles is readily shown by adding fragments of an insoluble substance of a specific gravity nearly equal to that of the fluid. These will be carried along with the ascending and descending currents, and exhibit the circulation very clearly.

62. It is evident from the constitution of gases that they must be heated by means of a similar circulation, when the heat is applied beneath. The only method of ascertaining the actual conducting power of fluids and gases, must, therefore be, to apply the heat at the upper surface; as, in this case, all that is communicated to the particles below must be in virtue of this power. Careful experiments have ascertained that fluids, with the exception of the fluid metal, mercury, are very imperfect conductors. Dr. Trail placed a thermometer horizontally in a small vessel of dried wood, and covered the bulb to the depth of half an inch with various liquids; he then brought an iron cylinder an inch in diameter, and heated to 212° F., into contact with the surface of the fluid, and observed the time required to raise the thermometer 3° F.

In mercury this effect was produced in 0' 15".

In water in 7' 5".

In alcohol in 15' 40".

The slowness with which water is heated from above is strikingly shown by setting fire to a small quantity of ether on its surface, in a tin or glass vessel. An equal quantity of water may be boiled by being placed over the flame, while that beneath is scarcely rendered warm.

The extreme mobility of the particles of a gas ren-

ders it difficult to ascertain their power of conduction. It is certain, however, that it is exceedingly imperfect.

63. *Radiant Heat*.—We have thus seen that all bodies unequally heated, which are placed in contact with each other, tend to become of the same temperature. The same effect takes place at sensible distances. If a heated iron ball be suspended in an apartment, the heat will be diffused from it in all directions, and thermometers, at equal distances on every side, will be instantly and equally affected. The heat in this instance is said to be radiated, and is called radiant heat. It is diffused in the same manner as light is radiated, by the emanation of particles in all directions in right lines; for the effect upon the thermometer instantly ceases when any object is interposed between it and the ball. It is not communicated by the conducting power of the air, for it passes downwards as freely as upwards, and it does not heat the air through which it passes, neither is its direction changed by a current of wind.

If a plane metallic mirror be placed opposite the heated ball, it will be found that the rays of heat which impinge against it are reflected, and that the law of reflection is the same as in the case of light, namely, the angle of incidence is equal to the angle of reflection. If smooth planes of different substances, such as glass, polished metal, wood, &c. are placed at equal distances from the ball, it will be found that they differ in their power of reflection. It is evident that all the rays which are not reflected must be transmitted or absorbed, and we, therefore, infer that those bodies which are not good reflectors must either absorb the rays and become heated, or transmit them and be diathermanous, that is, transparent as regards heat.

Most substances, it is found by experiment, absorb

the rays and become heated in the inverse ratio of their reflecting power. Few substances besides the gases transmit caloric without absorption.

64. Radiant heat must, it is evident, be capable of being converged to a focus when reflected from a concave surface, for this property is a consequence of the law of reflection above stated.

The most convenient apparatus for demonstrating this, and for ascertaining the radiating power of substances, is two concave metallic mirrors of the diameter of 12 or 18 inches, and a focal distance of 4 or 6 inches, mounted on stands. The mirrors are placed at a distance of 10 or 12 feet from each other, and one of the balls of a differential thermometer is placed in one focus, and the substance to be experimented on in the other. All the rays emanating from the substance that strike the mirror which is nearest to it, are reflected in parallel lines to the other mirror, and there converged to its focus. A heated ball in one focus will instantly raise the thermometer in the other, and that this is owing to the reflection of the mirrors, may be proved by intercepting the direct rays from the ball to the thermometer, which will not affect the instrument; while it is instantly lowered by placing a glass plate between it and its nearest mirror, so as to prevent the passage of the reflected rays.

65. A convenient way of ascertaining the radiating power of bodies is to place a cubic vessel of polished tin, filled with hot water, in one focus, and then to observe the effect upon the differential thermometer in the other, when the side of the vessel next to the mirror is coated with different substances. The numbers in the following table represent the rise in the thermometer when exposed to the influence of the respective radiating substances, for equal intervals of time, and, therefore, exhibit their relative radiating power:

Lampblack, water (by estimate)	100
Writing paper	98
Resin	96
Crown glass	90
Indian ink	88
Ice	85
Minium, isinglass	80
Plumbago	75
Tarnished lead	45
Mercury	20
Clean lead	19
Iron, polished	15
Sheet tin, gold, silver, copper	12

66. In general the more polished and smooth a surface, the more feeble the radiation. Organic substances are generally good, and the metals very bad, radiators, although the power of the latter is much increased by making their surface rough. Heat is radiated altogether from the surfaces of bodies, and although the radiating power of a very thin film of jelly was increased by an additional layer, it reached its maximum when the film had attained the thickness of the 1000th part of an inch.

That the absorbent power of surfaces is precisely proportional to their radiating power, may be proved by means of a large differential thermometer, the bulbs of which are hemispherical chambers, of considerable size, with the flattened surfaces towards each other; midway between them is placed a glass vessel with equal plane surfaces, facing those of the bulbs. One of the sides of the vessel and of the bulb is left uncovered, and the other is coated with a film of some feebly radiating substance. The vessel is then filled with hot water, and, when the coated sides are turned towards each other, the liquid in the tube of the thermometer is instantly affected, and recedes from that bulb which is the best radiator and absorber. When the coated side of the vessel is turned

to the uncoated bulb, the worse radiating to the better absorbing surface, the liquid in the tube is stationary, thus establishing the exact equality of the absorbing and radiating powers.

67. If a ball of ice be placed in the focus of one of the mirrors, the thermometer in the other will in that case become the greater radiating, because it is the hotter body, and will indicate a loss of heat.

Pictet placed the mirrors sixty-nine feet apart, and ascertained that no perceptible interval of time was occupied by caloric in traversing that space.

These experiments must be performed with metallic mirrors, for glass mirrors absorb so much of the caloric as to produce a very slight effect upon the thermometer.

Leslie determined the reflecting power of several bodies as follows:

Brass	100
Silver	90
Tin foil	85
Block tin	80
Steel	70
Lead	60
Tin foil softened with mercury	10
Glass	10
Do. coated with wax or oil	5

68. The power of bodies to intercept radiant heat is influenced by the conducting power of their particles, and the absorbing power of their surfaces jointly, as is shown by the following experiment. When two panes of glass, each coated on one side with tin foil, were used as a screen, they intercepted all the heat when the coated surfaces were the external ones; when these surfaces were placed together, the effect on the thermometer was to reduce it from 100° to 18°.

In this experiment, the radiant heat, which was altogether reflected by the tin foil, when placed ex-

ternally, was, after having been absorbed by the glass, conducted by the tin when this metal was surrounded by glass.

69. *The law of cooling.*—Sir Isaac Newton supposed the law of cooling to be such, that the heat lost by hot bodies in equal intervals of time, was a constant fraction of the excess at the beginning of each interval. Thus if a body heated 100 degrees above the surrounding temperature, were to lose $\frac{1}{10}$ of that excess, in 10° in the first second, it would lose $\frac{1}{10}$ of the remaining excess of 90° or 9° in the next second, and so on. It is now known that this is only an approximation to the law of cooling, and that its quickness, so far as it depends on the temperature of the hot body, increases as the terms of a geometrical progression *diminished by a constant number*, when the temperature of the hot body increases in arithmetical progression.

70. *Transmission of radiant heat through solids.*—It is evident, as has been said, that when radiant heat impinges upon a surface, it must either be reflected, absorbed, or transmitted. The fact that the absorbing power of most solid bodies, is in the inverse ratio of their reflecting power, proves that few solids are diathermanous. The metals are absolutely opaque to radiant heat.

The heat of the sun passes with its light through most transparent bodies without loss. But of the heat of incandescent bodies, a portion only, (which increases with the temperature) passes through solid media, such as screens. Non-luminous radiant heat is also transmitted by bodies in various proportions; and it is found that this property of diathermancy is altogether independent of transparency.

71. By means of instruments of extreme sensibility, Melloni ascertained the laws which regulate the transmission of radiant heat through various bodies.

The following table exhibits the results obtained

by transmitting radiant heat from various sources, through plates 1-10th of an inch in thickness of the several bodies mentioned. Out of one hundred rays emanating from the source, these were transmitted as follows:

		Flame of a lamp.	Ignited Platinum.	Copper. 734°	Copper. 912°
Rock Salt,	-	92	92	92	92
Fluor Spar,	-	78	69	42	33
Calcareous Spar,	-	39	28	6	0
Plate Glass,	-	39	24	6	0
Gypsum,	-	14	5	0	0
Alum,	-	9	2	0	0
Ice,	-	6	0	0	0
Sulphate of Copper,	-	0	0	0	0

It thus appears that heat of all temperatures passes freely through rock salt, which is to radiant heat what perfectly clear glass is to light; while on the other hand alum and ice, which are nearly transparent, arrest nearly the whole of the heat, and sulphate of copper is absolutely impermeable to it. It is also evident that the penetrating power of heat increases with the temperature. Plate glass, which allows nearly all the solar heat to pass, intercepts 61 per cent. of the rays from a lamp, and all the rays from copper at 212°. A plate of alum intercepts 91 per cent. of the direct rays from the lamp, while a second plate intercepts only 10 per cent. of those which have passed through the first. Calcareous spar, which intercepts 61 per cent. of the direct rays, intercepts 9 per cent. of the heat which had passed through alum, and 11 per cent. of that which had passed through gypsum.

On the other hand, a green tourmaline intercepts 82 per cent. of the direct rays, 99 per cent. of those which had passed through alum, and 70 per cent. of those which had passed through black glass.

72. If the rays from a lamp be made to pass through a prism of rock salt, a luminous spectrum

will be formed, and it is found that there is a perfectly distinct spectrum of radiant heat accompanying it, the most refrangible rays of which are near the middle of the luminous spectrum, while the least refrangible ones extend far beyond the least refrangible luminous rays. Rock salt allows *all the rays* to pass with equal facility; a plate of alum intercepts all but the least refrangible rays, while a plate of rock salt covered with soot, allows only those most refrangible to pass. It thus appears that the action of different media upon radiant heat is precisely similar to that of transparent coloured bodies upon light, and that heat like light consists of rays of unequal refrangibility, which may be separated by the spectrum, and are absorbed and transmitted in various proportions by various bodies.



CHAPTER III.

LIGHT.

73. The close resemblance between light and heat, and the influence which light exerts over chemical phenomena, render some notice of its properties necessary in this introduction.

Light is emitted in straight lines, in all directions, by a luminous body.

The quantity of light which falls on any given surface, is therefore in the inverse ratio of the square of the distance from the luminous point.

Light is communicated with inconceivable rapidity. It passes over 195,000 miles in a second, and is eight minutes in traveling from the sun to the earth.

When light falls upon any body it may, like radiant heat, be reflected, transmitted, or absorbed.

74. Reflection.—The reflection of light takes place at the surface of bodies, which must be smooth and polished. Liquids and polished metals are the best reflectors of light; when light is reflected, the incident and reflected rays are in the same plane, and that plane is perpendicular to the reflecting surface. The angles formed by these rays with a line perpendicular to the reflecting surface, are called the angles of incidence and reflection, and these angles are always equal to each other. It is in virtue of this property that light is converged to the focus of a concave mirror. Light is not reflected by gaseous bodies, but it is reflected by the clouds and other aqueous particles floating in the atmosphere. Bodies which reflect all the light that falls upon them are called opaque.

75. Refraction.—Transparent bodies are those through which light passes freely in a straight line. When it passes from one medium into another of a different density, or into a denser or rarer part of the same medium; it undergoes a change of direction at the plane of junction of the two media, unless the ray is perpendicular to that plane. This change is such that in passing from the rarer into the denser medium, the ray is always bent towards a line drawn perpendicular to the plane that separates the two densities, and vice versa. In this case the ray of light is said to be refracted.

The more dense a substance becomes, the greater is its power of refracting light. Inflammable bodies have a refractive power from two to seven times greater than incombustible substances of equal density.

The refractive power of water is shown by putting a piece of money in the bottom of a basin and then placing it so as to be barely hid by the rim of the vessel; if the basin be then filled with water, the piece of coin will be fully visible.

76. Index of Refraction.—The direction of the

incident and refracted rays is always in a plane perpendicular to the common surface of the media, and whatever angle the incident ray makes with a line drawn perpendicular to that surface, it bears a constant relation to the angle between the same perpendicular and the refracted ray. This relation is such that the sine of the angle of incidence and that of the angle of refraction are in a constant ratio for the same medium.

This remarkable law furnishes us with a very concise mode of expressing and comparing the refractive powers of bodies. The sine of the refracted ray being taken as unity, the sine of the incident ray is a constant quantity, and forms what is called the *index of refraction*. Thus the index of refraction for water is 1.336, and for the diamond 2.755.

It is the refraction of light in passing through glass plates with convex surfaces that enables us to converge it to a focus and thereby to construct optical instruments of great magnifying power. This branch of the investigation does not however belong to chemistry.

77. Composition of Light.—When the light of the sun is received upon one of the sides of a plane triangular prism of glass, an image or spectrum of coloured light will be formed on the wall of the room in which the experiment is made. This spectrum consists of red, orange, yellow, green, blue, indigo, and violet, in the order enumerated; the red being the colour which suffers the least refraction. If this spectrum be received upon the surface of a large lens, the light will be converged and a round spot of white light be formed in the focus. It is therefore evident that the white rays are a compound light, formed by the union of the colours of the solar spectrum.

78. If a piece of coloured glass be interposed between the prism and the spectrum, it will absorb

some of the rays and transmit the others. By means of this absorption it has been proved by Sir David Brewster, that the solar ray is actually resolved into red, yellow, and blue light; and that these colours are all present with various degrees of intensity, in every part of the spectrum. They are each most intense near the middle of their apparent place in the spectrum, and diminish gradually in intensity from that point. The other colours, orange, green, indigo, and violet, are formed by the union of the adjacent primitive colours.

79. *Calorific Rays.*—It is probable that there are rays of light to which the eye is insensible, in the same manner as the ear is insensible to certain sounds. For it is ascertained that rays, which do not affect the eye, exist beyond each extremity of the solar spectrum. Sir William Herschell examined the heating power of the several colours of the spectrum, and found that it was least at the violet end, and gradually increasing, became greatest at the extremity of the red: by placing the thermometer beyond the red end of the spectrum, he found that it continued to rise, and that the most intense heating power was always beyond the red ray, where there was no light at all.

80. *Chemical Rays.*—It is well known that the light of the sun destroys certain colours, and revives certain metals from their oxides, besides producing other chemical changes. There is a substance called chloride of silver, which is white when first prepared, and slowly becomes darkened by exposure to the diffused light of day; but blackens in a few minutes in the direct rays of the sun. Upon exposing this substance to the solar spectrum, it is found that the red, orange, and yellow, produced no effect; in the green it is slowly blackened; the effect increases in approaching the violet end, and is greatest at a point beyond the spectrum.

We thus learn that there are rays in the spectrum which do not affect the eye; that some of these which are less susceptible of refraction, or as it is termed, are less refrangible than the least refrangible of the visible rays, are calorific rays, and others which are more refrangible than the violet, are chemical rays. The calorific rays appear to be diffused over the least refrangible, and the chemical rays over the most refrangible end of the spectrum, and they increase in intensity as they approach their respective points of maximum.

Sir John Herschel has discovered that the solar spectrum imparts a tint corresponding to that of the light, upon paper properly prepared with chloride of silver.

81. *The Daguerreotype.*—The most surprising effect of the chemical rays is that produced in the process of Daguerre for fixing the images of the Camera Obscura. This is done upon plates of silvered copper. They are covered with a fine film of iodine by exposure to its vapour, and are then placed for a few seconds in the focus of a camera obscura. When taken out there is no visible image impressed, but a short exposure to the vapour of mercury brings out the magical picture with a distinctness, brilliancy, and softness, which no language can describe. The theory of this process is not yet understood, but the effect is owing to the chemical rays; for a red, or orange light produce a feeble effect; green objects are scarcely defined, while a deep blue is more powerful than a brilliant white light.

82. *Colours of Bodies.*—The colours of bodies are supposed to be owing to their absorbing some of the rays of the spectrum, and to their reflecting those which give them their colour. In proof of this, bodies take the colour of the light to which they are exposed. White bodies reflect and black bodies ab-

sorb all the rays. The solar ray being a compound of light and heat, or a union of luminous and caloric rays, bodies which are exposed to it become heated. Dark coloured substances acquire a higher temperature by exposure to the sun's light than white bodies.

83. Light produced by combustion and high degrees of heat, has the same properties in respect to chemical agency, refraction, and reflection, as solar light. It differs in respect to its composition, according to the substance from which it emanates. The light from the flame of an alcoholic solution of strontia, is red;—the flame of a similar solution of boracic acid, or of the salts of copper, is green; that from one of soda, is yellow. A portion of the heat which is in union with the light of burning bodies, is in the state of ordinary radiant heat, and will not pass with the light through a thick plate of glass, while another portion appears to be united with the light as in the solar ray, and is capable of refraction along with it.

84. *Phosphorescence*.—Many bodies by exposure to the solar ray absorb light, and emit it again when brought into a dark place. Canton's phosphorus, which is made by heating to a red heat, in a covered crucible, a mixture of three parts of calcined oyster shells, and one of flowers of sulphur, possesses this property. This power of emitting light in the dark, is called phosphorescence. It is possessed by many insects and marine animals and by certain vegetables in the living state. Light is also emitted during the processes of crystallization, and of putrefaction.

CHAPTER IV.

ELECTRICITY.

85. In speaking of the constitution of firm solids and crystals, it was stated that we must conceive their particles to be endued with points of attraction and repulsion. This property of polarity, as it is termed, is exhibited by various bodies under different circumstances.

86. *Magnetism*.—There is a peculiar ore of iron, which has been known for ages, on account of its property of attracting pieces of iron. This stone is called the magnet, and its properties may be communicated, by several different methods, to metallic iron.

The best form of the iron for these experiments is that of a straight bar or needle. It will be found that a bar of iron to which the power of attracting other pieces of iron has been communicated, possesses the following properties.

87. If it is poised on its centre so as to move freely in a horizontal plane, it will remain, when at rest, in a nearly north and south direction; and the same end will always point in the same direction. The two ends of the magnetised bar, or magnet as it is called, are termed its poles, and are distinguished, according to the direction in which they point, as the north and south poles.

88. If either pole of a magnetised bar, vibrating freely on its axis, be approached by the same pole of another magnet, they will repel each other; and if it be approached by the opposite pole they will attract each other.

If two magnetised bars of equal magnitude and power, be placed together, the north pole of each, in

contact with the south pole of the other, their magnetic force is neutralised, and they no longer possess the power of attracting iron.

89. If a magnet be placed beneath a sheet of paste-board or paper, and iron filings be scattered over the paper, each particle will itself acquire magnetic polarity, and they will arrange themselves in regularly curved lines around the poles of the large magnet beneath.

The science which investigates these phenomena is called Magnetism.

90. *Electricity from Friction.*—Attractive and repulsive forces, analogous to those of the magnet, may be developed in other bodies, by friction and various other means.

91. If amber, resin, sulphur, and glass, for example, be rubbed with dry silk or cloth, they acquire the power of attracting light bodies; the property ceases after a while, but may be renewed at pleasure by the same means.

After the light body has remained for a short time in contact with that which has been *excited*, as it is termed, by friction, the attractive force is changed into a repulsive one, and the body is driven off.

92. Small balls of pith suspended by dry silken strings, are very convenient for the performance of these experiments. If a pith ball thus suspended, after being attracted and then repelled, have the excited body again brought near it, it will be repelled. nor can they without external force be again brought in contact. If two pith balls be thus suspended from the same point, they will, after contact with the excited body, not only be repelled by it, but they will repel each other. The more dry the atmosphere, the longer will these phenomena continue.

93. If the balls instead of being suspended by a dry silken string, be attached to a wet string, or thread, or wire, none of these phenomena take place,

except the original attraction of the excited body, and this ceases almost immediately.

We thus learn that there are certain substances which dissipate, or carry off, or conduct the attractive forces developed by friction. These substances are said to be conductors, and those which do not possess this power, are called non-conductors of this attractive force. These attractive and repulsive forces were first observed in amber, or electron, as this mineral was called by the Greeks. They are therefore called electrical forces, and the science which investigates their effects is called Electricity.

94. A conducting body may have the power of electrical attraction and repulsion imparted to it, provided it be surrounded by non-conductors, in which case it is said to be insulated. The friction of two insulated conductors will excite electricity. A convenient way of insulating a conducting body, is to place it on a support of glass or resin.

If a pith ball, suspended by a non-conducting string, be brought into contact with a roll of excited resin or sealing wax, the power of attraction and repulsion will be communicated to it, and it is said to have become charged.

95. If we excite a tube or rod of glass, it will communicate its charge to an insulated pith ball, in the same manner as resin, first attracting and then repelling it.

But if the excited glass tube be brought near the pith ball, which has been charged from an excited piece of resin, instead of repelling it, it attracts it; and in like manner, excited resin attracts the pith ball which has been charged by excited glass. Pith balls that have been charged, the one by glass and the other by resin, also attract each other.

It thus appears that while glass and resin repel the bodies to which they have imparted their own electricity, they each attract the bodies that have

been charged by the other. We therefore infer, that there are two kinds of electricity, each of which repels its own kind and attracts the other. The electricity developed in glass, is called vitreous or positive, and that in amber and resin, resinous or negative electricity.

96. *Electricity from Induction.*—Let a small metallic cylinder, one or two inches in diameter, and six or seven inches long, terminating in hemispherical ends, be insulated by supporting it on a glass rod. Let two pith balls be suspended by thread or wire, from each end of this cylinder. If an excited rod of glass or sealing wax be brought near it, the balls at each end will diverge from mutual repulsion, showing that electrical forces have been developed in the cylinder, by the mere approach of an excited body. If this body be withdrawn, the balls coalesce, proving that the electrical forces have ceased to operate. If, while the balls are divergent, from the presence of the excited body, an excited glass rod be brought near them, it will be seen that one set will be attracted and the other repelled, proving that they are charged with different kinds of electricity. With whichever kind the body, the presence of which imparted electricity to the cylinder, was charged, the balls nearest to it will be oppositely, and those farthest from it, similarly electrified.

If while the excited body be still near, the remote end of the cylinder be touched with the finger, the balls at that end will instantly collapse; if the excited body be then removed, they will again diverge, and it will be found upon trial that both pairs are charged with the electricity of the pair at the end nearest the excited body.

97. *Theory of Electricity.*—In order to explain these phenomena, which are the fundamental facts of the science of electricity, it seems necessary to make the following supposition.

In consequence of the mutual attraction of the vitreous and resinous electricities, the state of rest or equilibrium of the electric fluids must be that of combination, and it is accordingly supposed, that in all bodies which do not exhibit electrical forces, the two fluids, which are universally diffused throughout nature, are in a state of combination. This combination may be disturbed in a variety of ways, and especially by friction. When two electric bodies are rubbed together, the vitreous electricity of both, accumulates in one, and the resinous in the other; when a body thus excited is surrounded by a non-conducting medium, such as a dry atmosphere, the electricity is not dissipated; but it is found that a stratum of the medium immediately surrounding the excited body, becomes oppositely electrified, and that this is surrounded by another stratum similarly electrified with the body itself.

98. This phenomenon is supposed to be caused by the electricity of the excited body disturbing the equilibrium of the surrounding medium, repelling its own kind, and attracting the opposite, so as to surround itself by an atmosphere of the latter within one of the former. This mode of disengaging or setting free the combined, or latent electricities of a body, is said to be by induction.

As long as none of the free electricity of the external stratum is carried off by the surrounding bodies, the mutual attraction of the two oppositely electrified strata keeps their electricities in tension, and that of the inner stratum does not exhibit any tendency to combine with the opposite electricity of the excited body. But if any portion of the electricity of the outward stratum is carried off by conduction, an equal portion of that of the inner stratum is left free, and combines with a portion of the electricity of the excited body, which in this manner gradually parts with its charge.

99. The application of these principles to the explanation of the experiment with the insulated cylinder is obvious. The excited body being brought near one end, disturbs the electrical equilibrium, attracting the opposite electricity towards itself, and repelling its own kind to the extreme end of the cylinder, as is shown by the opposite electrical conditions of the suspended pith balls. When the extreme end of the cylinder is touched with the finger, the electricity accumulated there is carried off, and if the excited body be then withdrawn from the other end, the opposite electricity there accumulated is diffused over the whole cylinder.

100. In the common electrical machine, the electrical fluids are set free by the friction of the silk rubber against the glass plate or cylinder. The resinous electricity excited in the rubber is carried off by a communication with the ground, and the vitreous electricity developed in the cylinder is transferred to the prime conductor, where it accumulates. The discharge of the accumulated electricity from the conductor is accompanied with a crackling noise, and with a flash of light or spark, which is at times several inches long.

101. *The Leyden Jar.*—The Leyden Jar is usually a glass bottle with a wide mouth, coated on both sides to within a few inches of the top, with tin foil. A wire terminating at the top in a knob, and communicating with the internal coating, by the other end, passes through the stopper of the bottle. When the knob of the jar is presented to the prime conductor, it receives an electrical charge which is diffused over the inner coating. The electricity thus diffused disturbs the electrical equilibrium of the outer coating, attracting the opposite electricity, and repelling that of the same kind with itself.

If the jar be insulated, and a brass knob, communicating with the ground, be brought near the out-

side coating, it will be seen that a spark passes to the latter, whenever one passes from the prime conductor to the knob of the jar. This spark is occasioned by the passage of the repelled electricity to the ground. The opposite electricities of the outer and inner coating maintain themselves in what may be called a forced equilibrium, by means of their mutual attraction. As long as a free passage is afforded to the repelled electricity of the outside of the jar, there does not appear to be any limit to the quantity of electricity, which may be thus accumulated, other than the strength of the glass to resist the passage of the fluid through its substance, and the distance of the coatings from each other over the top of the jar.

When a communication is made between the outer and inner coating, by touching the former and the knob of the bottle with a metallic rod, the natural electrical equilibrium is restored, and the discharge of the jar is accompanied with a loud report, and a brilliant flash of light.

102. There is evidently a strong affinity between the attractive forces thus developed, and those possessed by the magnet. In both cases there appear to be two kinds of forces, and those bodies, or those portions of the same body, which are endued with the one, repel other bodies endued with it, and attract those endued with the opposite force. In both cases the tendency of these forces is to accumulate at the extremities of a body, especially if it be in the shape of a long ellipsoid or a needle. The attractive forces developed in the magnet are permanent, while those excited by the friction of electrics are fugitive. No such tendency as the north and south polarity of the magnet is observed in excited electrics, although by means of electricity powerful magnets may be made, and north and south polarity be communicated to metals not susceptible of permanent magnetism.

103. *Electricity from Chemical Action.*—The natural equilibrium of the electric fluids may be disturbed, not only by friction and induction, but by chemical action.

When a plate of zinc and a plate of copper are placed in a vessel of water, and the extremities which are not immersed, are connected by means of a wire or other perfect conductor, it will be found that a feeble current of vitreous electricity is transmitted through the conductor from the copper to the zinc plate, while a current of resinous electricity passes in an opposite direction.

If the communication be interrupted, the currents cease entirely, but they continue as long as a passage for the electric fluid is maintained. The force of this current is greatly increased by adding to the water a little sulphuric acid, which increases the chemical action to which this development of electricity is owing.

It is found that unless one of the metallic plates is more powerfully acted on by the fluid than the other, there is no disengagement of electricity, and it is also ascertained that the current of vitreous electricity always flows through the connecting wire, from the plate that is least acted on to the other.

104. This branch of physical science is due to the genius of two celebrated Italian philosophers, Galvani, and Volta. An accidental occurrence led the former to a knowledge of its fundamental facts, and the science has received the name of *Galvanism*, to commemorate its discoverer. To the latter we are indebted for the discovery of these electric circuits, which are usually called Voltaic circles. The instrument formed by connecting a number of simple circles, is called the voltaic, or galvanic battery.

105. When a copper plate is partially immersed in dilute nitric acid, it is attacked by the acid, nitrous acid vapours are disengaged, and the metal is

oxidised and converted into a nitrate. If a plate of zinc be partially immersed in the same solution, it is also immediately oxidated and converted into a nitrate. But if the two plates be connected by means of a wire, the action upon the copper plate ceases at once; the zinc alone is oxidated, and there is a disengagement of hydrogen gas at the surface of the copper plate.

When zinc and copper plates, each cemented to a glass handle, are brought into contact, and the zinc is then applied to an electrical condenser, it is found to have acquired a positive or vitreous charge, and the copper in like manner is ascertained to have become negative or resinous.

106. *Voltaic Circles.*—As it appears to be essential to the disengagement of electricity that the chemical action on the metallic surfaces should be of unequal intensity, it is manifest why three elements are necessary to form one of these electrical, or, as they are called, *voltaic circles*.

These may be either two perfect conductors and one imperfect one, as in the case just given, or one perfect conductor and two imperfect ones. A circle of the latter kind may be made by cementing a plate of zinc into a box, so as to form two separate cells, which are filled with liquids that act unequally upon the opposite surfaces of the metal; with a solution of salt, for example, in one cell, and with diluted nitric acid in the other. In this case the circuit must be completed by forming a communication between the liquids by means of a bent wire, and the current of vitreous electricity passes through the wire, from the liquid of the less chemical action to that having the greater.

In all these cases the electrical current is set in motion by the decomposition of the water. Its oxygen unites with that metal which has the greater affinity for oxygen, and its hydrogen is disengaged

at the other metal, while portions of the electric fluids set free at the metallic surfaces, flow in opposite directions through the connecting wire; that of the vitreous electricity being uniformly from the metal least acted on to the other.

107. Simple voltaic circles may be formed of various materials, for metallic substances are not essential to the production of electrical currents. They can be produced by layers of charcoal and plumbago, of slices of muscle and brain, or of beet root and wood. Other liquids than water may also be used with metals, such as a fused metallic chloride, iodide, or fluoride. What is requisite, is, that the fluid should be decomposable by electricity, and that it should act with more energy on one of the metallic surfaces, than on the other.

The simple voltaic circle in ordinary use is composed of a pair of zinc and copper plates excited by an acid solution. The form and size of the apparatus varies exceedingly; in one of the most advantageous, the copper is made into an oblong narrow cup for containing the liquid; and the zinc plate is fixed between its sides with interposed blocks of wood to prevent contact. A more convenient form is a cup, made of two cylinders of sheet copper of unequal size, placed one within the other, and soldered together at the bottom, so as to leave an intermediate space for containing the zinc cylinder, and the acid solution. Two small copper cups, attached by wires to the upper edge of the zinc and copper cylinders, are useful appendages; for by filling them with mercury, the voltaic circuit may be closed or broken with ease and expedition.

Another kind of circle may be formed by coiling a sheet of zinc and copper round each other, so that each surface of the zinc may be opposed to one of copper, and be separated from it by a small interval; an apparatus of this kind has been made of plates

60 feet in length. Dr. Hare contrived this arrangement and called his apparatus the calorimotor, on account of its great power in igniting metals.

108. The intensity of the electricity, set in motion by a single pair of plates, is so feeble, that it requires the aid of a delicate apparatus to render it perceptible.

By connecting a number of these simple circles together, the intensity of the electrical current may be increased at pleasure.

By the term *intensity*, is meant the energy or effort with which a current is impelled, and which is altogether independent of the *quantity* of the fluid set in motion.

109. *The Galvanic Battery.*—The first combination described by Volta, consisted of a vertical series of zinc and copper plates, each pair separated from those adjoining by pieces of cloth somewhat smaller than the plates: and moistened with a saturated solution of salt. In these compound circles, it is essential that the same order of arrangement of the metals be preserved throughout the whole, that is, if the zinc plate be the lower one of the upper pair, it must be the lower one of all the others. For, as the vitreous electricity always flows from the copper to the adjoining zinc plate, and as the electrical energy, or intensity of the whole pile, is the sum of the energy or intensity of the several circles that compose it, it is evident that if the order be inverted in any number of pairs, the direction of the current will also be inverted, and the effect of an equal number of pairs differently arranged will thereby be neutralized.

The quantity of the electricity disengaged, depends upon the intensity of the chemical action, and it is found that this is a maximum at the moment when the fluid and plates come in contact. In order therefore, to obtain this maximum in a compound circuit, it is requisite that the chemical action should take place

in all the pairs of plates at the same moment, which cannot be effected in the pile.

110. The old arrangement of the pile has therefore been abandoned, and the best batteries are now constructed on the plan of Dr. Hare, by soldering plates of zinc and copper together, and cementing them in a box, in grooves at the distance of a quarter of an inch apart. To the box containing the plates is attached lengthwise, another box of equal dimensions, for containing the acid solution when the battery is not in use. The whole turns on an axle so as to admit of the fluid being poured into all the cells at the same instant by a quarter revolution of the axle. The trough turns on copper pivots that rest on copper bearings, and have a metallic communication with the extreme plates, so that the electrical circuit can be completed by attaching wires to the fixed copper bearings.

The acid solution is made by mixing 100 parts, by measure, of water with $4\frac{1}{2}$ of sulphuric acid and 4 of nitric acid.

111. In all these arrangements, the maximum effect is produced at the moment of immersion, and the intensity of the chemical action continually decreases. This is found to be owing to the decomposition of the sulphate of zinc, by the copper plate and the consequent precipitation upon the latter, of a film of metallic zinc, which operates by reducing the extent of the copper surface that is exposed to the chemical action.

112. *Daniell's constant Battery*.—Professor Daniell has constructed a battery in which the surface of the copper is kept bright by a constant deposition of metallic copper on its surface, and in which the action is maintained for many days without the least diminution. Each cell of this battery is a cylindrical copper vessel of $3\frac{1}{2}$ inches in diameter, within which is a cylindrical vessel of porous earthenware. A

rod of amalgamated zinc occupies the centre and rests by a cross piece of wood upon the earthen cylinder. The space within the latter is filled with water acidulated with one eighth part of its bulk of oil of vitriol, and the space without, with the same liquid saturated with sulphate of copper. A shelf is placed on the outside of the earthen cylinder, on which solid sulphate of copper is placed, so as to keep the solution constantly saturated. A battery thus constructed of twenty similar cells is capable of decomposing the alkalies, and of exhibiting the most interesting phenomena of voltaic electricity.

113. *Theory of Electro-chemical Action.*—In these experiments the water between the metallic surfaces is decomposed, the oxygen appearing at the zinc, and the hydrogen at the copper surface. The former unites with the metal, the oxide which is thus formed is dissolved by the acid, and the metallic surface of the plate is in this way kept clean.

Yet, although the oxygen is thus disengaged at one surface and the hydrogen at the other, it seems certain that there is no conveyance of either gas through the water. It is the oxygen of the aqueous particles in contact with the zinc, that accumulates on that surface, and the hydrogen of the particles in contact with the copper, that accumulates there. In order to explain these phenomena, we must suppose that the particles which compose the voltaic circuit assume opposite polarities. Thus we may conceive that the zinc plate attracts the negatively electrified oxygen of the particle of water next to it, setting the hydrogen free, which unites to the oxygen of the next particle, and so on; at the same time the negatively electrified copper attracts the positive hydrogen of the particle of water in contact with it, and the oxygen with which it was united is set free, and unites with the atom of hydrogen of the adjoining particles, set free by the attraction of the zinc, for its oxygen. In this way there is a simultaneous and continuous

decomposition and recomposition of the particles of water in a line between the two plates.

The negative electricity which was in combination with the oxygen is thus set free, and accumulated at the zinc plate, and the positive electricity which was in combination with the hydrogen is set free and accumulated at the copper plate, and, being attracted by each other, currents of vitreous and resinous electricities are established along the connecting wires in opposite directions; namely, a current of the former, from the copper to the zinc, and of the latter, from the zinc to the copper.

114. It is found that the quantity of electricity set in motion, is exactly in proportion to the energy of chemical action between the positive plate, and the solution in which the plates are immersed, and also that the peculiarities which distinguish this action from ordinary chemical action, namely, that it is altogether suspended in respect to one plate and greatly increased in respect to the other; cease, when the continuity of the circle is broken.

115. When the extremities of the wires which complete the circuit in a voltaic battery, instead of being brought into contact, are immersed in a vessel of water, the electrical current decomposes the water. The vitreous current that passes from the copper plate, attracts the negative oxygen of the adjoining particle of water, and the resinous current from the zinc plate, attracts the positive hydrogen of the particle of water next to it, and a series of decompositions and recompositions of the particles, in a straight line between the wires, takes place simultaneously.

The surfaces, whether metallic or non-metallic, at which the positive and negative electricities are disengaged in the voltaic circuit, are termed electrodes by Faraday, from *ηλεκτρον*, and *οδος*, a way. He distinguishes them into anode and cathode, the former being the electrode at which the positive electricity is sup-

posed by him, to enter, and the latter, that by which it leaves the liquid. The anode may be more accurately stated to be the electrode, at which the negative, and the cathode, that at which the positive electricity accumulates, the former corresponding to the zinc, and the latter to the copper surface of the battery.

116. The current of electricity thus established along the connecting wires of a voltaic battery, not only produces chemical decomposition, but will ignite and melt metallic wires, charge a Leyden jar, and exhibit all the phenomena of ordinary electricity.

117. *Influence of the electric current on the magnetic needle.*—If a magnetic needle be placed along side of and parallel to the connecting wire of a voltaic circuit, the needle will deviate from its position, according to certain invariable laws. If the needle be suspended so as to vibrate in a horizontal plane, and be placed *above* the connecting wire, the pole which is next the positive electrode will be deflected to the right, which, where the line of direction of the wire and the magnet is north and south, will be to the westward. If it be placed under the wire, the same pole will be deflected to the left or to the east. If the needle be suspended so as to vibrate in a vertical plane, and be placed on the right or western side of the wire, the pole which is next to the positive electrode will be deflected towards the ground, and when placed on the left or eastern side, will be deflected upwards.

118. *The Galvanometer.*—It is found that the angle of deflection bears a constant relation to the quantity of the electrical fluid which passes along the wire, and this property of electrical currents in deflecting a magnetic needle, furnishes a delicate method of ascertaining their existence and quantity. An instrument called a *galvanometer*, has been constructed for this purpose. It consists of several rec-

tangular coils of wire, separated from each other by being wound round with silk, and communicating with the positive electrode by one end, and with the negative by the other. A delicately suspended magnetic needle is placed in the plane of the rectangle, and as the current, in its progress along the wire, passes repeatedly above and below the needle in opposite directions, the whole tendency, both of the upper and lower current, is to deflect the needle in the same direction. The degree of deflection is measured on a graduated arc attached to the needle.

119. *Electricity from the unequal distribution of Heat.*—The disturbance of the electrical equilibrium, which is caused by friction and chemical action, is also caused by the unequal distribution of heat. A wire of uniform density and thickness shows no signs of electricity when one end of it is heated. But if there be any obstacle to the passage of the heat, a current of positive electricity will begin to flow from the heated part towards the point where the obstacle exists. So likewise if heat be applied to the point, at which two bars of different metals are soldered together, and their free extremities be connected by a wire, a feeble voltaic circle will be formed; and if cold, instead of heat, be applied to the point of union, the direction of the electric current will be reversed. The metals which by their combination exhibit these phenomena, are bismuth, platinum, lead, tin, copper or silver, zinc, iron, and antimony; the first and last named being the most powerful combination, and the current of positive electricity flowing through the wire from the first to the last mentioned metal.

120. *The Thermo-multiplier.*—Several pairs of bars of bismuth and antimony may be joined together, so as to form a compound circle, possessing a very feeble electricity, but strongly affecting a magnetic needle. The thermo-electric pile, as it is termed, is the most delicate and accurate measure of the

changes of temperature that has yet been discovered. Melloni used an instrument of this kind in his admirable researches into Radiant Heat. Thirty pairs of slender bars or needles of bismuth and antimony, being soldered together, two by two, at their alternate ends, and packed into a cylindrical case, were connected by their extreme ends with a very delicate galvanometer. These bars were so slender, that the circular area of the containing case was not larger than the bulb of an ordinary thermometer; and so delicate was the instrument, that the heat of the hand at the distance of thirty feet, sensibly affected the needle of the galvanometer.

THE
PRINCIPLES OF CHEMISTRY.

PART FIRST.
INORGANIC CHEMISTRY.

CHAPTER I.

THE PONDERABLE ELEMENTS.

121. **THE** infinite variety of ponderable substances by which we are surrounded, results from the various combinations of a few elements. Those substances which have hitherto resisted all our efforts to decompose them, are regarded as simple elementary bodies. The number of these bodies at present known is fifty-five, and they may be divided into two great classes, metallic and non-metallic. Those belonging to the former class are distinguished by being conductors of electricity, by their opacity, and by a peculiar lustre which is termed the metallic lustre. Bodies of the latter class are distinguished by being non-conductors of electricity, by being more or less transparent, and by the absence of the metallic lustre. It will be most convenient to describe the latter class in the first place.

SECTION I.

The Non-metallic Elements.

122. These are thirteen in number, viz:

Oxygen,	Carbon,
Chlorine,	Boron,
Iodine,	Silicon,
Bromine,	Sulphur,
Fluorine,	Phosphorus,
Nitrogen,	Selenium.
Hydrogen,	

123. *Oxygen*.—Oxygen is one of the most abundant substances in nature. It forms about a fifth part of the atmosphere, more than a third part of the solid crust, and eight-ninths of the waters of the globe. It enters into the composition of nitre, (nitrate of potassa,) red lead, (red oxide of lead,) black oxide of manganese, chlorate of potassa, and most acid and saline compounds. It was thought at one time to be the sole acidifying principle, and was therefore named oxygen, from *οξύς*, acid, and *γενναω*, to generate.

Oxygen gas was discovered by Priestley in 1774, and called by him *dephlogisticated air*. Scheele, without any knowledge of Priestley's discovery, obtained it a year or two afterwards, and called it *empyreal air*; it was also termed *vital air* by Condorcet.

124. Oxygen gas may be obtained by heating, to a red heat, the pulverised black oxide of manganese in an iron flask, to which a bent tube is attached, and collecting the gas in the inverted jar of a pneumatic trough. The oxide consists of manganese 27.7, and oxygen 16, and parts with one fourth part of the

latter. Every 43.7 grains of pure oxide yield four grains or 12 cubic inches of oxygen gas.

Oxygen gas may be obtained sufficiently pure for ordinary purposes, by heating nitre (nitrate of potassa) to a red heat in an iron flask. The salt is decomposed, and every 102 grains will yield about sixteen grains or 36 cubic inches of gas. It is, however, less pure than that obtained by the former, or the following process.

Oxygen is obtained in the purest state and greatest quantity, in decomposing by heat the chlorate of potassa in a retort, the glass of which contains no lead. This salt contains, in every 122½ grains, 48 grains of oxygen, which are separated by heat, so that an ounce troy of the salt yields 187 grains, or 543 cubic inches of gas.

125. Oxygen gas is destitute of taste or smell. Its specific gravity is to that of atmospheric air as 1.1026 to 1; 100 cubic inches of oxygen gas, when the temperature is at 60° F. (15.5° C.) and the barometer at 30 inches, weigh 34.2 grains.

Oxygen gas refracts light less than any other known substance. It is a non-conductor of electricity, and is the most perfect negative electric known. It has never been obtained uncombined in any other form than that of a permanently elastic fluid or gas.

Water dissolves oxygen gas very sparingly, 100 cubic inches absorbing but about three or four cubic inches of the gas.

126. One of the most remarkable properties of oxygen gas is its power of supporting combustion. If a taper or piece of wood, on which the slightest spark is visible, be plunged into a vessel of oxygen gas, it is immediately rekindled and burns with great brilliancy. Phosphorus burns in it with so vivid a light as to be painful to the eye. Charcoal burns with beautiful scintillations, and the combustion of

iron or steel wire exhibits still more dazzling coruscations. All substances that are capable of burning in the open air, burn in oxygen gas with still greater brilliancy. It is found that the gas is itself consumed in this process, which is merely a rapid combination of oxygen with the burning body, accompanied by the extrication of light and heat.

127. Oxygen gas is necessary to the support of animal life, for no animal can live in an atmosphere which does not contain uncombined oxygen gas. Air, from which the oxygen has been abstracted by a burning body, or by chemical affinity, is instantly fatal to an animal. An animal cannot live long in pure oxygen gas, for the system becomes highly excited, debility ensues, and the animal dies from over excitement.

Oxygen combines with all the other elementary bodies, forming compounds that are termed *oxides* or acids.

128. *Chlorine*.—Chlorine is one of the component parts of common salt, which is extensively diffused in nature as a rocky mineral, and which also forms about three parts in a hundred of the waters of the ocean.

Chlorine was discovered by Scheele in 1774, and called by him dephlogisticated marine acid. It was called oxygenated muriatic or oxy-muriatic acid, by the French chemists, who erroneously supposed it to be an acid.

129. Chlorine is obtained from common salt by mixing three parts thereof, with one part of black oxide of manganese, two parts of sulphuric acid, and two parts of water. The mixture is gently heated in a glass retort, and the chlorine collected in a vessel over hot water.

130. Chlorine is a permanently elastic fluid of a yellowish green colour, and derives its name from

χλωρος, green. Its taste is astringent, and its odour very disagreeable and suffocating. It is one of the most fatal to animal life of all the gases. Its specific gravity is 2.47, and 100 cubic inches of the gas at 60° F. and 30 in. Bar. weigh 76.5988 grains. Under the pressure of four atmospheres, chlorine becomes a liquid of a bright yellow colour, which remains fluid at very low temperatures.

Both in the gaseous and liquid state, it is a non-conductor of electricity and a negative electric. Hot water does not absorb this gas, but cold water absorbs twice its volume at the common pressure, and yields it again when heated. When moist chlorine gas is exposed to a temperature of 32° F. (0° C.), yellow crystals are formed, which are a combination of chlorine and water.

131. The most powerful means of chemical decomposition which we possess have hitherto failed to produce any change in chlorine, and it is therefore to be regarded as a simple elementary substance.

Chlorine resembles oxygen, in being in some respects a supporter of combustion. A lighted taper burns in it for a short time with a small red flame, and emits a large portion of smoke. Tin, copper, arsenic, antimony, zinc, when in a state of powder, or fine leaves, and phosphorus, take fire spontaneously in chlorine gas, and combine with it.

Chlorine combines with nearly all the other elementary bodies, forming compounds that are called *chlorides*.

132. A very remarkable property of this element is its power of destroying animal and vegetable colours, and the volatile odoriferous principles of putrefying organic matter, and contagious effluvia. Colours that have once been removed by it cannot be restored. Its property of destroying contagious effluvia, has been extensively and successfully ap-

plied to the fumigation of hospitals in cases of contagious disease.

Chlorine may be known by its peculiar colour and suffocating smell. When the hand is plunged into a vessel of this gas, a very perceptible degree of warmth is felt.

The presence of chlorine in any compound may be detected by a solution of the nitrate of silver, a salt hereafter to be described. It occasions, in the compounds of chlorine, a white precipitate, which becomes black by exposure to light.

133. *Iodine*.—Iodine exists in sea water and in the water of certain saline springs, and enters into the composition of many marine plants and zoophytes. It was discovered in the year 1812, by Courtois, a manufacturer of nitre at Paris.

Iodine is prepared from the impure alkaline salt formed by burning sea weeds. This alkali is refined for the use of the manufacturers of soap, and the liquors which remain after the crystallization of the salt, contain it in considerable quantities.

134. Iodine is a soft, friable, opaque solid, closely resembling micaceous iron ore in colour and lustre, and like that mineral it is usually in crystalline scales. It crystallizes in large rhomboidal plates, the primitive form of which is a rhombic octohedron.

The specific gravity of iodine is 3.08. It fuses at 225° F. (107° C.), and boils at 347° F. (175° C.), and when it is moistened with water it sublimates at low temperatures. Its vapour is of a rich indigo or violet colour, and hence it derives its name from the Greek word *ιοδης*, violet coloured. The density of this vapour is 8.716, according to Dumas, and 100 cubic inches weigh 269.8638 grains.

Iodine is a non-conductor of electricity, and a negative electric. Its taste is acrid, and its odour strongly resembles that of diluted chlorine. Water dissolves about one seven thousandth part of its

weight of iodine, and the solution has a yellowish brown colour. It is readily soluble in alcohol and ether, communicating to those liquids a deep reddish-brown colour.

Iodine combines with most of the elemental bodies, and its compounds with them are called *iodides*.

Its action upon vegetable and animal colours, resembles that of chlorine, although it is more feeble.

The presence of iodine may be known by the violet hue of its vapour. A more delicate test is starch, with which it forms a compound of a deep blue colour; and so delicate is this test, that it will communicate a perceptible blue tint to a liquid containing one part in 450,000 of iodine.

135. *Bromine*.—Bromine was discovered in 1826, by Balard of Montpellier. It exists in nature associated with iodine, and is obtained from the same substances as that element, which it closely resembles in its properties.

It derives its name from the Greek word *βρωμος*, signifying a strong offensive odour.

136. Bromine, at the ordinary temperature, is a liquid of a garnet colour, so deep as to be almost opaque. Its odour resembles that of chlorine, being highly disagreeable and suffocating. Its specific gravity is 3. At the ordinary temperature it emits deep red-coloured vapours; at 116.5° it boils, and between 0° and -4° it becomes a brittle solid. Bromine is a non-conductor of electricity. It is a negative electric, and has resisted all attempts to decompose it. It is soluble in water, alcohol, and ether, and when exposed to a temperature of 32° , in contact with water, forms a hydrate that crystalizes in beautiful red octohedral crystals.

The vapour of bromine extinguishes a lighted taper, the flame of which becomes green at the base and red in the upper part, before going out.

Some inflammable substances take fire by contact

with bromine. It acts with energy on organic substances, stains the skin yellow, and bleaches solutions of litmus and indigo.

The presence of bromine may generally be ascertained by means of chlorine, which disengages it from most of its combinations.

Bromine combines with nearly all the elemental bodies, and its compounds are called *bromides*.

137. *Fluorine*.—This element is so called from the mineral termed Fluor Spar, of which it is a component part. Although fluorine has been isolated, yet the difficulty of procuring vessels on which it does not act, has prevented its accurate examination. At the ordinary temperature it is a gas of a yellowish brown colour, which has an odour resembling chlorine and burnt sugar, and which bleaches vegetable colours. It is the only simple element which has not been made to combine with oxygen.

138. *Nitrogen*.—Nitrogen enters into the composition of atmospheric air, forming about four fifths of the atmosphere. Its peculiar properties were first noticed by Dr. Rutherford of Edinburgh, in 1772. Lavoisier in 1775, ascertained it to be a constituent part of the atmosphere, and called it azote, from α , and $\zeta\omega\eta$ life. Its present name was applied to it on account of its being the base of nitric acid.

Nitrogen is most conveniently prepared by burning phosphorus in a small floating cup, under a bell glass in a pneumatic trough. The sole product of combustion is phosphoric acid, which is speedily absorbed by the water, leaving only nitrogen in the receiver. If the vessel be graduated, it will be seen that the portion consumed, which is oxygen gas, amounts to one fifth of the whole quantity.

Nitrogen gas is colourless, and devoid of smell and taste. It does not change the blue colour of vegetables, and is characterized by negative, rather than positive qualities. It is not a supporter of com-

bustion, but extinguishes all burning bodies that are immersed in it. It is not inflammable. It is not a supporter of animal life, although it has no deleterious properties, but causes death by the privation of oxygen.

One hundred cubic inches of water absorb one and a half cubic inches of this gas. Its specific gravity is .9727, and 100 cubic inches weigh 30.165 grains. Nitrogen refracts light feebly. It has never been decomposed, nor has it been compressed into a fluid. It is an electro-positive element, appearing at the negative electrode, when compounds that contain it are decomposed by electricity.

139. *Hydrogen*.—Hydrogen, so termed from ὑδωρ, water, and γεννέω, to generate, is one of the elements of water. Its properties were discovered by Cavendish, in the year 1766, and it was named by him inflammable air. It was also called phlogiston, from the supposition that it was the matter of heat.

Hydrogen exists naturally as a gas, and has never been liquefied. It may be obtained by passing the vapour of water through a tube filled with iron wire, kept at a red heat. The oxygen unites with the iron, and the hydrogen which is set free, may be collected in convenient vessels by dipping the end of the tube in the water of a pneumatic trough. A more convenient method of obtaining it, consists in submitting fragments of iron or zinc to the action of dilute sulphuric acid, consisting of one part of acid to four or five of water. The oxygen of the water unites with the metal, and the hydrogen is set free.

140. Pure hydrogen gas has neither smell, taste, nor colour. As commonly prepared, it has a faint, disagreeable smell, owing to the impurity of the materials from which it is prepared.

141. It refracts light more powerfully than any other gas, having 6.6 times as great a refractive power as atmospheric air. Its specific heat is also

greater than that of any other body, being to that of air as 13.08 to 1, and to that of water as 3.88 to 1. It is the lightest of all known ponderable bodies, being 300,000 times lighter than platinum; and its specific gravity being .0689, or precisely 16 times lighter than oxygen gas, so that 100 cubic inches weigh 2.1367 grains.

Hydrogen gas is highly inflammable, and burns with a yellowish blue flame, and feeble light. When mixed with $2\frac{1}{2}$ times its bulk of atmospheric air, it detonates violently by the electric spark, or the approach of flame. The explosion is far more violent when the hydrogen is mixed with half its bulk of pure oxygen gas.

Hydrogen gas extinguishes the flame of a lighted taper immersed in it, and destroys animal life. It is not however immediately deleterious, as the lungs may be inflated with it a few times in succession, without injury.

142. When a stream of hydrogen, or other detonating gas issues from a small aperture, it speedily blends with the atmospheric air, and, if set on fire, burns in a series of continued but feeble explosions. These may be rendered audible by burning the jet in a tube of glass, or other material; which gives musical sounds of great variety of intonation, according to the size of the flame or the tube.

One hundred cubic inches of water absorb $1\frac{1}{2}$ cubic inches of hydrogen gas.

143. A large quantity of heat is evolved in the combustion of hydrogen gas, the quantity of ice melted by burning a pound, being estimated by Lavoisier at 295.6, by Dalton at 320, and by Dr. Crawford at 480 pounds. The most intense heat that has yet been procured, is caused by burning hydrogen in oxygen gas. In Dr. Hare's blowpipe the gases are collected in separate vessels, and conducted from them through tubes terminating in a common aper-

ture, at which the jet of the mixed gases is inflamed. In Newman's blowpipe, as now modified, the gases are condensed by a syringe into a strong metallic box, and burned at the extremity of a tube, the interior of which is filled with closely packed layers of wire gauze, that effectually prevent the flame from communicating to the explosive mixture in the box.

Hydrogen unites with the other simple elements, giving rise to a great number of compounds. It is the electro-positive element in most of those combinations. Its compounds are called hydrogurets.

144. *Carbon*.—Carbon is one of the most extensively diffused elements in nature. It is found in crystals, which are termed diamonds; graphite, or black lead is almost pure carbon; and it is obtained nearly pure, in the form of charcoal, by burning wood in close vessels, so as to expel all the volatile portions. Neither acids nor alkalies have any action on it.

145. Diamond, or crystallized carbon, is one of the rarest and most highly prized substances in nature. It occurs in perfect crystals, and in roundish grains of crystalline structure. Its primitive form is the octohedron, and its secondary crystals are usually curvilinear polyhedrons. Its structure is lamellar, with joints parallel to the faces of the primitive crystal.

It is satisfactorily shown from the optical properties of the diamond, that it must originally have been soft, and that it was formed by a slow concretion. Dumas found the diamond when burnt, to leave behind a slender skeleton of inorganic matter. It is in general colourless, but sometimes with a tinge of gray, blue, red, yellow, green, brown, or black; its lustre is highly splendid, and it refracts light powerfully; its sp. gr. is 3.52, and it is the hardest substance in nature. It is infusible, and un-

dergoes no change by exposure to the most intense heat in a close vessel, but slowly consumes away when heated to a white heat in the open air, and burns with great brilliancy in melted nitre.

146. Anthracite coal and graphite are included in the same mineral species, and consist of carbon in a state of great purity. Graphite differs from anthracite in being soft and unctuous to the touch, and in leaving a grey streak on paper. It is this property which renders it so useful a material for drawing pencils. Graphite may be formed artificially, by exposing charcoal to the action of melted iron. Its sp. gr. is 2.5, and it conducts heat and electricity. Graphite crystallizes in rhombohedrons, so that carbon is a di-morphous element. It is perfectly opaque, and is often found in brilliant lamellar hexagonal tables.

147. Charcoal is black, porous, hard, and brittle; it conducts heat very slowly, and is a good conductor of electricity. It is insoluble in water, and has scarcely any action upon acids or alkalies. It is infusible, and undergoes no other change by exposure in a close vessel to the most intense heat, than becoming so firm and hard as to scratch glass.

148. Recently prepared charcoal, dry and yet warm, gradually absorbs large quantities of several kinds of air, the greater part of which is expelled when it is again heated to a red heat. The quantity thus absorbed is, in the case of some of the readily liquefied gases, 90 times its own volume. It absorbs 1.75 times its bulk of nitrogen, 7.5 of hydrogen, and 9.25 of oxygen.

From this cause, fresh burned charcoal increases from 9 to 18 per cent. in weight, by exposure to a damp atmosphere. Charcoal also absorbs the odorous and colouring matters of most animal and vegetable substances. When meat which has been tainted, is carefully washed in cold water, and then

boiled in water in which pieces of red hot charcoal have been plunged, it is entirely sweetened. When coloured or odoriferous liquids are filtered through freshly burned charcoal, they are deprived of the greater part of their colour and smell. The most efficacious charcoal for this purpose is prepared from animal matters, and it loses its property after being used, but has it restored by heating anew to redness with a fresh portion of animal matter.

When strongly heated in the open air, charcoal burns slowly without smoke or residue. In oxygen gas it burns rapidly, and with brilliant scintillations. The compounds of carbon are called carburets.

149. *Boron*.—A salt, known by the name of borax, has long been obtained from India as an article of commerce, being highly valued as a flux by the workers in metals. This salt is a compound of the alkaline base, soda, and a peculiar acid, which has received the name of boracic acid.

Boracic acid itself was ascertained by Davy, in 1807, to be a compound of oxygen, with a peculiar and hitherto undecomposed base, that is termed Boron.

Boron is obtained in the form of a dark olive coloured powder, tasteless, inodorous, insoluble, and infusible. It bears the most intense heat in close vessels, without change, and when heated in the open air to 600° , it suddenly takes fire and burns, being converted into boracic acid. Its specific gravity is about 2. and it is a non-conductor of electricity.

Boron is obtained by heating potassium with boracic acid, in a copper tube. They combine with the extrication of much light and heat, and the boron is freed from impurities by washing with warm water.

150. *Silicon*.—One of the most extensively diffused substances in the mineral kingdom, is the earth

called *silex*, in its various modifications of quartz, rock crystal, and sand. Sir Humphrey Davy brought pure *silex* into contact with the vapour of potassium, and found that it was decomposed, and the potassium converted into an oxide by the oxygen which it had abstracted from the *silex*. He thus ascertained *silex* to be a combination of oxygen, with a peculiar undecomposed substance, which is separated in the above experiment, and to which the term *silicon* has been given.

151. Silicon is an infusible solid, of a dark nut-brown colour. It is a non-conductor of electricity. When first prepared it is soluble in a solution of chlorohydric acid, and of caustic potassa; although the sulphuric and nitric acids, even at a boiling heat, have no action on it. It burns readily and vividly in the open air, and becomes coated with *silex*. If this coating be removed, the silicon beneath is found to have been condensed and altered by the heat, to which it has been exposed. It is now perfectly incombustible, and no longer soluble in chlorohydric acid, or caustic potassa.

Silicon burns vividly when brought into contact with carbonate of potassa, or soda, at a temperature below that of redness.

152. *Sulphur*.—Sulphur is found in a state of purity in volcanic countries, and also exists in large quantities in combination with iron, and other metals. It is obtained for commercial purposes by distillation from these combinations.

Sulphur also exists in organic bodies, being found in the yolk of eggs, and in black mustard seed.

153. Sulphur, like carbon, is a dimorphous body. It is found native, and it crystallizes from its vapour, and from certain solutions, in the form of the right rhombic octohedron. On the other hand, the crystals obtained by slowly cooling a mass of melted sulphur, till a crust is formed, and then pouring the

interior liquid from the surrounding solid mass, are transparent, oblique, rhombic prisms; after a few days, these crystals undergo a molecular change, become opaque, and full of fissures in the plane of the right rhombic octohedron, which is the form of the native crystal.

154. Sulphur is a brittle solid, of a light yellow colour. It is insoluble in water and alcohol, is tasteless, emits a peculiar odour, and becomes negatively electrified when rubbed, and is a non-conductor of electricity. Its specific gravity is 1.99. It is volatile and fusible, begins to evaporate at 170° , and to fuse at 205° . At 220° it is completely fluid, but when heated to 350° , it becomes a soft tenacious solid, and acquires a reddish-brown tint. If sulphur in this state be plunged in cold water, it forms a plastic transparent mass, which slowly regains the hardness of common sulphur, and is much used for taking fine impressions of coins and medals. At 482° it again becomes liquid and boils at 600° . It is now rapidly volatilised, and condenses in detached crystalline grains, which form what is termed the flower of sulphur.

The vapour of sulphur has a deep yellow colour, and the specific gravity of 6.648.

When sulphur is heated in the open air, it kindles spontaneously. It burns slowly with a faint blue light at 180° or 190° , and with so small an evolution of heat as not to inflame gunpowder. At 300° its combustion is more rapid, and in oxygen gas it burns vividly with a bluish white flame.

155. The vapour of sulphur is a supporter of combustion. If a piece of sulphur be dropped into a gun-barrel heated at the butt end to a red heat, and the sulphurous vapour which is formed be forced in a stream from the touch hole, iron wire will take fire in it and burn as brilliantly as in oxygen gas.

Sulphur combines with the other elementary bodies and its compounds are called sulphurets.

156. *Phosphorus*—Phosphorus was discovered in 1669, by Brandt, an alchemist of Hamburg.

It is prepared from the ashes of burnt bones, which consist of lime combined with phosphorus and oxygen, forming phosphoric acid. They are mixed with water, and digested with half their weight of sulphuric acid, which partially decomposes the phosphate of lime. The clear liquid is separated by filtration, evaporated to the consistence of syrup, mixed with one fourth its weight of charcoal powder, and strongly heated in an earthen retort, the beak of which is plunged in water. The charcoal decomposes the phosphoric acid, and the phosphorus distils over in drops, and is collected under the water.

157. Pure phosphorus is transparent and almost colourless. It has the consistence and lustre of wax. It fuses at 108° , and boils at 550° . Its specific gravity is 1.778, and it crystalizes in octohedrons. When melted phosphorus is cooled by being suddenly plunged in cold water, it becomes black and opaque, but recovers its original aspect, by fusion and slow cooling.

Phosphorus is exceedingly inflammable; it burns in common air with a bright white light, and its combustion in oxygen gas is brilliant in the highest degree. It undergoes slow combustion at common temperatures in atmospheric air, emitting a white vapour, an alliaceous odour, and a faint light which is visible in the dark. It must therefore be preserved under water. The presence of very small quantities of the vapour of ether, or oil of turpentine, or of olefiant gas, prevents the slow combustion of phosphorus at low temperatures.

Phosphorus takes fire spontaneously by pressure, friction, and percussion. It is soluble, by the aid of heat, in the essential oils. Its compounds are termed phosphurets.

158. *Selenium*. — Selenium was discovered by Berzelius, and so called from *σεληνη*, the moon, because of its resemblance to the metal tellurium, in combination with which it exists, and for which he at first mistook it. It is found in minute quantities, combined with sulphur, and some of the metals.

At the ordinary temperature it is a brittle solid, which is opaque, and of a dark leaden grey colour, and metallic lustre, when in masses of some thickness, but translucent and of a rich garnet colour, when in thin films, and of a deep brick red when reduced to powder.

Its specific gravity is 4.3. It melts at a temperature somewhat above that of boiling water, and softens at 212° , and may then be drawn out into fine transparent threads of a red colour. At 650° it boils, and is converted into an inodorous vapour of a deep yellow colour. It is sublimed in close vessels, and condensed again without change. It conducts heat and electricity imperfectly, is insoluble in water, and unchanged by exposure to the air.

It combines readily with oxygen when heated, and tinges the flame of the blowpipe of a light blue colour, exhaling so strong a smell of decaying horse-radish that $\frac{1}{36}$ th of a grain will fill a large apartment with the odour.

SECTION II.

The Metals.

159. The metals constitute a more natural assemblage than the non metallic elements, and yet when we attempt to define them, there are but two qualities in which they all agree, namely, the peculiar lustre called metallic, and the power of conducting heat and electricity. Even in these there is a wide difference between the extremes, and the passage

from the non metallic to the metallic elements is gradual and not sudden. Thus sulphur and selenium are more closely allied to arsenic and tellurium, than either of them to many of the elements under their own class.

160. Until the discovery of the metallic bases of the alkalies, which are lighter than water, the metals as a class were distinguished by their great weight; the specific gravity of iridium, the heaviest body known being 21.8, and that of chrome 5.

161. *Malleability and Ductility*.—Some of the metals admit of being beaten into thin plates or leaves. The malleable metals are, gold, silver, copper, tin, platinum, palladium, cadmium, lead, zinc, iron, nickel, potassium, sodium, and solid mercury. The remaining metals are brittle, and some of them so much so as readily to be reduced to powder.

Most of the malleable metals admit of being drawn out into wire, although the same metal does not always possess both qualities in the same degree. Gold, silver, platinum, iron, and copper, are the most ductile metals.

162. *Tenacity*.—The tenacity of the metals varies greatly, as will be seen by the following table, stating the number of avoirdupois pounds sustained by a wire .787 lines in diameter,

Iron wire	lbs. 549.25
Copper	302.778
Platinum	274.32
Silver	187.137
Gold	150.753
Zinc	109.54
Tin	34.63
Lead	27.621

The tenacity of metals is greatly lessened by the process of annealing, which is that of very slow cooling.

163. Metals differ greatly in *hardness* and *elasticity*. Titanium, manganese, and iron, will scratch

glass, while lead, potassium, and sodium, may be scratched by the finger nail. Iron and copper are the most elastic metals, and their sonorousness depends upon this quality.

164. *Crystallization*.—Many of the metals have a distinct crystalline structure. Iron is fibrous; zinc, bismuth, and antimony are lamellated. Many of them may be obtained in distinct crystals, by slow cooling from their liquid state, and pouring out the melted metal from the surrounding solid mass. The resulting crystal is almost always the cube or regular octohedron.

165. *Fusibility*.—Mercury is naturally liquid. Potassium and sodium fuse below the boiling point of water. Cadmium, tin, bismuth, lead, tellurium, arsenic, zinc, and antimony, fuse below a red heat. Silver, copper, and gold, fuse at a full red heat. Cobalt, nickel, iron, manganese and palladium require the highest heat of a smith's forge to fuse them; and the remaining metals can only be perfectly fused by the oxyhydrogen blowpipe, or in the galvanic circuit.

Cadmium, mercury, arsenic, tellurium, potassium, sodium and zinc, are volatile.

166. The metals are forty-two in number and may be conveniently arranged as follows:

First Group.

Metals forming acids with oxygen.

Tellurium,	Manganese,
Arsenicum,	Titanium,
Antimony—Stibium,	Columbium,
Chromium,	Uranium,
Vanadium.	Osmium,
Molybdenum,	Tin—Stannum,
Tungsten,	Gold—Aurum.

Second Group.

Metals forming neither acids nor alkalies, but heavy, earthy, and mostly coloured oxides.

Platinum,	Lead—Plumbum,
Palladium,	Zincum,
Rhodium,	Cadmium,
Iridium,	Copper—Cuprum,
Nickelum,	Iron—Ferrum,
Silver—Argentum,	Cobaltum,
Mercury—Hydrargyrum,	Cerium,
Bismuthum,	Lanthanum.

Third Group.

Metallic bases of the Earths.

Aluminium,	Thorium,
Yttrium,	Zirconium.
Glucinium,	

Fourth Group.

Metallic bases of the Alkaline Earths.

Magnesium,	Strontium,
Calcium,	Barium.

Fifth Group.

Metallic bases of the Alkalies.

Lithium,	Sodium—(Natrium,)
Potassium—(Kalium.)	

167. *Tellurium*.—Tellurium was discovered in 1798, by Klaproth. It is a rare metal, found only in small quantities in the gold mines of Transylvania.

Its colour is intermediate between that of tin and lead. It has a bright metallic lustre, and lamellated structure. It is very brittle; its specific gravity is 6.115; it fuses at a heat below redness, and is volatile at a red heat. Before the blow-pipe it burns rapidly with a blue flame, bordered with green, and is dissipated in gray-coloured pungent fumes.

168. *Arsenicum*.—Arsenic is sometimes found na-

tive, but more frequently in combination with sulphur, iron, cobalt, and other metals.

It is exceedingly brittle, has a bright metallic lustre, a crystalline structure, and a steel-gray colour. At 356° it sublimes slowly without liquefying, and in condensing crystallizes in rhombohedrons. Its fusing point has not been ascertained. Its specific gravity is 5.88. Its vapour has a strong odour of garlic. It tarnishes by exposure to the air, and when heated in contact with oxygen, is rapidly converted into a white oxide.

169. *Antimonium*.—Antimony was discovered in the 15th century, by Basil Valentine. It is sometimes found native, but its principal ore is the sulphuret, from which it may be obtained, by heating the powdered ore, with half its weight of iron filings, in a covered crucible. Antimony is a brittle metal, of a light bluish gray-colour, having a lamellated structure. It possesses considerable metallic lustre, which tarnishes by exposure to the air. Its specific gravity is 6.7. It fuses at 810° , and may, by very slow cooling, be obtained in crystals, the primitive form of which is a rhombohedron.

When heated to a white heat in a covered crucible, and then suddenly exposed to the air, it takes fire and burns with a white light, and with the formation of white vapours that condense into small acicular crystals having a silvery lustre.

170. *Chromium*.—Chrome was discovered in 1797, by Vauquelin. The principal ore of chrome is its combination with iron. It is also found united with lead.

Chromium is a brittle metal, almost infusible, of a yellowish white colour, and a distinct metallic lustre. It is scarcely acted on by the most powerful acids. Its specific gravity is 5. It is also obtained in the form of a black powder, which acquires a metallic lustre by pressure, and takes fire when heated in the open air.

171. *Vanadium*.—Vanadium was discovered in 1830, by Sefström in Swedish iron, although its existence as a distinct metal had been announced in 1801, by Del Rio, of Mexico. Vanadium is found combined with iron and with lead. It has generally been obtained from its ore in the form of a heavy black powder, which assumes, under a strong pressure, a lustre like that of graphite, and which takes fire at a red heat. It may also be obtained in a crystalline mass, having a brilliant metallic lustre, and a white colour, and which is so brittle, that it falls to powder upon being moved. It is not oxidised by air or water at common temperatures.

172. *Molybdenum*.—Molybdenum was announced as a distinct metal in 1778, by Scheele, who did not, however, succeed in separating it from its ore. It is usually found combined with sulphur, or with lead.

It is a brittle, grayish white, and almost infusible metal. Its specific gravity is 8.6. When heated in open vessels, it combines with oxygen and forms an acid.

173. *Tungstenum*.—Tungsten is so called from the Swedish words, *tung sten*, heavy stone, on account of the density of its ores.

It is a metal of a grayish white colour, having a brilliant lustre. It is nearly as hard as steel, and almost infusible. Its specific gravity is 17.6. It takes fire when heated in the open air.

174.—*Manganese*.—Manganese was first obtained in a metallic state by the Swedish chemist, Gahn. It is found combined with oxygen in the form of a black oxide. It is a hard, brittle metal, of a grayish-white colour, and granular structure. Its specific gravity is 8.013. It is exceedingly infusible; tarnishes by exposure to the air; absorbs oxygen rapidly when heated to redness, and slowly decomposes water at common temperatures.

175. *Titanium*.—Titanium was discovered by

Klaproth. It is found combined with oxygen in the mineral called rutile, or titanite. It has been obtained in the state of a deep blue-coloured powder, that takes fire in warm air.

Metallic Titanium is also found in minute cubic crystals, in the slag of certain iron works. These crystals have a bright metallic lustre, and the colour of copper. Their specific gravity is 5.3. They scratch rock crystal, and are exceedingly infusible. Exposed to hot air, they become covered with a purple film.

176. *Columbium*.—Columbium was so called by its discoverer, Hatchett, who obtained it in 1801, from a mineral found at New London, in Connecticut. Two years afterwards, Ekeberg obtained it from a Swedish mineral, and called it Tantalum. The identity of the two metals was proved by Wollaston in 1809.

Columbium is obtained in the form of a black powder that is a non-conductor of electricity, but which acquires a metallic lustre and an iron-gray colour, and becomes a conductor by pressure. It takes fire below redness, and burns with a vivid light. Its specific gravity and fusing point are not known.

177. *Uranium*.—Uranium was obtained by Klaproth in 1789, the year in which the planet Uranus was discovered, and received its name from this coincidence. Its properties are imperfectly known. It has been obtained by conducting hydrogen gas over its protoxide heated in a glass tube. The substance thus obtained, which was supposed to be metallic uranium, was crystalline, of a metallic lustre, and a reddish-brown colour. It suffered no change by exposure to air at common temperatures, but when heated, absorbed oxygen, and was reconverted into the protoxide.

178. *Osmium*.—Osmium is found in native platinum, from which it has been obtained in the state

of a black powder, that acquires a metallic lustre by friction. Its specific gravity varies from 7 to 10, according to its mode of preparation. It takes fire when heated in the open air, and is dissolved by fuming nitrous acid.

179. *Stannum*.—Tin was known to the ancients. It is found combined with oxygen, and is procured from its ore by the aid of heat and charcoal.

Tin has a white colour, and a lustre resembling that of silver, tarnishing very slowly by exposure to the air. It is so soft that it may be cut with an iron knife; it is inelastic and malleable. When bent backwards and forwards it emits a peculiar crackling sound. Its specific gravity is 7.2. At 442° it fuses, and its surface becomes covered with a gray powder. At a white heat it takes fire and burns with a white flame. It may be beaten into leaves of the thickness of the $\frac{1}{1000}$ th of an inch.

180. *Aurum*.—This metal has been known from the remotest antiquity. Gold is found in metallic grains among sand in the beds of rivers, and crystallized in octohedrons and cubes in rocky veins.

It is the only metal of a yellow colour. Its specific gravity is 19.257. It has a brilliant metallic lustre, which is not tarnished by the longest exposure to air and moisture. In ductility and malleability it surpasses all other substances. A grain of gold may be extended so as to cover 52 square inches, with a thickness not exceeding $\frac{1}{881000}$ of an inch, in which state it appears green by transmitted light. A grain of gold may also be drawn into a wire 550 feet long. Gold is very tenacious, though inferior in this respect to iron, copper, platinum, and silver. When pure it is exceedingly soft and flexible. It fuses at 2016° , and is not oxidated by being kept for months in a state of fusion in an open vessel. By means of the oxyhydrogen blowpipe, or the galvanic battery, it may be set on fire, and burns with a greenish blue flame.

Gold is readily dissolved by chlorine and fluorine.

181. *Platinum*.—This metal is found in Brazil, Peru, and the Uralian Mountains. It was discovered by Ulloa, in 1705. Platinum occurs only in a metallic state, in the same localities with gold.

Platinum is a metal of a white colour, which is less pure and brilliant than that of silver. It is, after iridium, the heaviest known substance, having a specific gravity of 21.25. It is a very soft, malleable, and ductile metal, and like iron, admits of being welded at a high temperature. It is a less perfect conductor of heat than several other metals. Like gold it undergoes no change by exposure, for any length of time, to air and moisture, and it is not melted or oxidated in the strongest heat of an air furnace, although it is fused by galvanism and the oxyhydrogen blowpipe. Chlorine is its only solvent.

Platinum is precipitated from its solution in chlorine in the form of a gray metallic powder. This powder possesses the remarkable property of effecting the inflammation of a mixture of hydrogen and oxygen gases. If a current of hydrogen gas be directed upon a small mass of this powder, it renders it red-hot, and soon takes fire. This property is possessed, in a less degree, by the thin leaf, the fine wire, and the filings of platinum, by gold, nickel, and several other metals. When the native platinum is digested in nitro chlorohydric acid, the solution is found to contain chlorides of platinum, *palladium*, and *rhodium*, and there is left a black powder which consists of osmium, iridium, and other metals.

182. *Palladium*.—This metal was discovered in 1803, by Wollaston. It exists in small proportions combined with native platinum.

It resembles platinum in colour and lustre, but is much harder and more fusible. It is ductile and malleable; its specific gravity is 11.3 to 11.8. It is unalterable by exposure to air and moisture, and is

oxidized and dissolved, by nitric, sulphuric, and chlorohydric acids.

183. *Rhodium*.—Rhodium was discovered by Wollaston, in 1803. It exists in combination with native platinum.

It is a brittle, extremely hard metal, of a white colour, with a specific gravity of about 11. It is not attacked, when pure, by any of the acids, and requires the strongest heat of a wind furnace for its fusion.

184. *Iridium*.—This metal is found in combination with native platinum. It was discovered along with osmium in 1803, by Tennant. It is so brittle, that it falls to powder when burnished. Its colour is that of platinum, and it is the heaviest and most infusible of all the known metals. Its specific gravity has been recently determined by Dr. Hare to be 21.8. It is acted upon with difficulty by the acids, and when finely divided is oxidated at a red heat.

185. *Nickel*.—Nickel is found in combination with arsenic and sulphur, and is also a constituent of those masses of native iron, which are supposed to be of meteoric origin.

It is highly ductile and malleable, has a brilliant metallic lustre, and a white colour intermediate between tin and silver. Its specific gravity is 8.279, which rises to 9. when hammered. It is attracted by the magnet and is susceptible of permanent magnetism, but loses this property at 630°. It is fusible with difficulty, and suffers no change by exposure to air and moisture at common temperatures.

186. *Argentum*.—Silver was well known to the ancients. It is found native, and in combination with many other metals, and with sulphur.

It is of a clear white colour, and exceeds all the pure metals in brilliancy. It is very soft, malleable, ductile, and tenacious. It crystalizes in octohedrons, and cubes. It may be beaten into leaves of the thick-

ness of $\frac{1}{1000000}$ th part of an inch, and drawn into a wire thinner than a human hair: a wire $\frac{1}{10}$ th of an inch in diameter will support 270 lbs. Its specific gravity is 10.474. to 10.51. It melts at a full red heat, and by an intense and long continued heat may be made to boil and evaporate away. Melted silver will absorb 22 times its volume of oxygen, with which it parts when becoming solid. In cooling from its fluid state, silver becomes covered with minute granulations in consequence of the escape of the oxygen, which it had absorbed. One or two per cent of copper destroys this property. It does not alter by exposure to air and moisture. In the galvanic circuit and the oxyhydrogen blow pipe, silver burns with vivid scintillations, and a light green flame.

Silver forms an insoluble compound with chlorine, which thus furnishes a ready test of its presence. It is dissolved freely by nitric acid.

187. *Hydrargyrum*.—This metal was well known to the ancients. Mercury or quicksilver is found native in small quantities; its principal ore is its combination with sulphur.

It is distinguished from all other metals by its fluidity at the common temperature. It has a white colour like that of tin, and a brilliant metallic lustre. At -39° or -40° , it becomes solid, and in congealing has a tendency to crystalize in octohedrons. Solid mercury is malleable and ductile; its specific gravity is 15.612, while that of the fluid is 13.568. At 662° it enters into ebullition and evaporates. Mercury is not altered by exposure to air and moisture at common temperatures. It is dissolved by chlorine, and by nitric and sulphuric acids.

188. *Bismuthum*.—Although this metal was known to the ancients, it was confounded by them with tin and lead. Bismuth is found native, and in combination with sulphur, oxygen, and arsenic.

It has a reddish-white colour, and considerable

metallic lustre. Its structure is highly lamellated, and it crystalizes in octohedrons and cubes. Its specific gravity is 9.8. It is brittle when cold, but may be hammered into plates when warm. At 476° it fuses, and at a red heat sublimes in close vessels, and burns with a bluish white flame in open ones. It conducts heat more slowly than most other metals. When fused it becomes covered with a gray film of oxide, and it is not much altered by exposure to air and moisture at common temperatures.

189. *Plumbum*.—Lead was known to the ancients. It is generally found combined with sulphur, in the ore called galena.

It is of a bluish-gray colour, and a brilliant metallic lustre, which speedily tarnishes by exposure to the air. It is very soft, flexible, and non-elastic, and is ductile, and highly malleable. It is the least tenacious of the ductile metals. Its specific gravity is 11.381. It fuses at 612° , but does not sublime at a white heat. When cooled slowly it forms octohedral crystals. Lead absorbs oxygen quickly at high temperatures, and becomes covered with a film of oxide.

190. *Zincum*.—Although the ancient Greeks and Romans were unacquainted with zinc, they used its ore, calamine, in the manufacture of brass. Zinc has long been known to the Chinese, but the method of extracting it from its ores was not known in Europe till the middle of the eighteenth century. Zinc is found in combination with sulphur in the mineral called blende.

It has a brilliant metallic lustre, a bluish-white colour, and a highly lamellated crystalline structure. Its specific gravity is 7. It is a hard metal, being acted upon with difficulty by the file. At low and high degrees of heat, it is brittle, but between 210° and 300° it is both malleable and ductile. It fuses at 900° , and when slowly cooled, crystalizes in four

or six-sided prisms. In close vessels it sublimes unchanged at a white heat, and when heated to a red heat, in a covered crucible, bursts into a flame when the cover is removed, burning with a brilliant white light, and being converted into a white flocculent powder.

Zinc undergoes little change by the action of air and moisture, but is rapidly acted upon by diluted sulphuric acid.

191. *Cadmium*.—Cadmium was discovered by Stromeyer, in 1817. It is found in combination with the ores of zinc.

It resembles tin in colour, lustre, and fusibility, but is harder and more tenacious. It is very ductile and malleable; its specific gravity is 8.604 to 8.694. It is nearly as volatile as mercury, and its vapour condenses in globules of bright metallic lustre. It absorbs oxygen in the open air, and is readily dissolved by nitric acid.

192. *Cuprum*.—Copper has been known from the earliest ages. It is found native and combined with sulphur. It is distinguished from all other metals, except titanium, by its red colour. It has a brilliant metallic lustre; it is ductile, malleable, highly tenacious, hard, elastic, and sonorous. Its specific gravity is 8.895. It fuses at 1996° F. being more fusible than gold, and less so than silver.

It is slowly oxidated by exposure to the air; nitric acid acts upon it with violence. At a high temperature copper takes fire and burns with a rich green flame. It is one of the best conductors of heat known; melted copper volatilizes water so rapidly as to occasion dangerous explosions, when it is poured into vessels containing the smallest portion of moisture. It does not decompose water at any temperature.

193. *Ferrum*.—Iron is the most abundant of all the metals; it is found in native masses of considerable magnitude, which are supposed to be of meteoric

origin. It is also found in combination with other metals, and with sulphur, and with oxygen, which last are its most abundant ores.

It has a peculiar gray, or bluish-white colour, and a bright metallic lustre, which is much increased by polishing. It is very ductile and malleable, and the most tenacious of all the metals. Its specific gravity is 7.7; its texture is fibrous, and it requires for its fusion the highest temperature of the wind furnace. At common temperatures it is very hard and unyielding, but at a red heat it becomes very soft and pliable, so that two pieces may be incorporated or *welded* together by hammering. It is attracted by the magnet, and may be rendered permanently magnetic. It is rusted or oxidated by exposure to the air and moisture; and is rapidly dissolved by dilute sulphuric acid. Iron is the only metal which takes fire by collision with flint. It becomes hot, and may be heated to a red heat by percussion. It burns with vivid scintillations in oxygen gas, and a bar of iron heated to a full white heat, may be made to burn in the open air by rapidly whirling it round. A circular disc of soft iron, made to revolve in a lathe, will cut the hardest steel, without being itself worn away.

When it is first obtained from its ores in the form of *cast iron*, it contains many impurities, such as carbon, and other metals. Cast iron fuses much more readily than pure iron, and acquires a granular texture in cooling. There are two kinds, the white and the gray; of which the former is exceedingly brittle, and the gray more soft and tenacious. The difference between them appears to be owing to changes dependent upon the rapidity of their cooling; for the former is converted into the latter by being strongly heated and slowly cooled.

When bars of the purest malleable iron are exposed for several days to a full red heat in contact with

powdered charcoal, they are converted into *steel*, a substance intermediate between pure and cast iron. It contains 1.3 to 1.75 per cent of carbon, is far inferior in ductility and malleability to pure iron, but greatly exceeds it in sonorousness, hardness, and elasticity. Its texture is more compact, and it is susceptible of the highest polish. It is more fusible than pure, and less so than cast iron, and forms *cast steel* by fusion.

Although cast iron and steel do not belong to the class of simple elements, yet the modifications they exhibit of the properties of iron are so slight as to render it most convenient to treat of them in this place.

194. *Cobaltum*.—Cobalt was discovered in 1733, by a Swedish chemist, named Brandt. It derives its name from Kobold, an evil spirit—a term applied to its ore by the German miners, before they were acquainted with its value.

Cobalt is a brittle metal, of a reddish-gray colour, a granular and sometimes lamellated structure, and feeble metallic lustre. It fuses below the melting point of iron, and crystalizes in irregular prisms by slow cooling. Its specific gravity is 7.834; it is feebly, but permanently, magnetic; it is slowly oxidized by heat and air, and burns in the oxyhydrogen blowpipe with a rich red or purple flame.

195. *Cerium, Lantium*.—Cerium, named after the planet *Ceres*, was discovered by Berzelius, in a rare Swedish mineral; and Lantium has recently been discovered in the same mineral by Mosander. Very little is known of their properties. Cerium has been obtained in minute grains as large as a pin's head, and is a white brittle metal.

196. *Aluminium*.—Aluminium is the metallic base of alumina, one of the most abundant of the earthy oxides.

It is obtained in the form of a gray powder, or small scales of the lustre and colour of tin. It re-

quires a greater heat than cast iron does, to fuse it. When heated to redness in the open air, in oxygen, or in chlorine gas, it takes fire and burns with a very vivid light. It is malleable and ductile, and is not tarnished by exposure to air and moisture at common temperatures.

197. *Yttrium*.—Yttrium is the metallic base of an earth found at Ytterby, in Sweden, and called from that circumstance Yttria.

Yttrium has been obtained in the form of metallic scales, of a grayish-black colour, and metallic lustre. It is brittle, and burns with splendour when heated to redness in atmospheric air.

198. *Glucinium*.—Glucinium is the metallic base of an earth called glucina, which has hitherto been found only in a few rare minerals, of which the emerald is the best known. Glucinium has been obtained in the form of a grayish-black powder, which acquires a dark metallic lustre by burnishing. It is not oxidised by exposure to air and moisture, but takes fire at a red heat in atmospheric air and in chlorine, and burns with great splendour.

199. *Thorium*.—Thorium is the base of an earth which has been found in a rare Norwegian mineral called thorite. It resembles glucinium in its properties.

200. *Zirconium*.—Zirconium is the base of the earth zirconia. It has been obtained in the form of metallic scales, although little is known of its properties.

201. *Magnesium*.—Magnesium is the base of the alkaline earth magnesia.

It has a brilliant metallic lustre, a white colour like silver, is very malleable, and fuses at a red heat. It is superficially oxidated in a moist atmosphere, but undergoes no change in dry air, or by boiling with water. It inflames spontaneously in chlorine, and as brilliantly when heated to redness in the open

202. *Calcium*.—Calcium is the metallic base of lime, and is a metal of a white colour, whose other properties are unknown.

203. *Strontium*.—Strontium is the metallic base of the earth, strontia; very little is known of its properties.

204. *Barium*.—Barium is the base of the earth baryta.

It is a metal of a dark gray colour, with a lustre inferior to that of cast iron. It sinks rapidly in strong sulphuric acid, and attracts oxygen with avidity from the atmosphere. It rapidly decomposes water, which it causes to effervesce strongly by the disengagement of hydrogen gas.

205. *Lithium*.—Lithium is the metallic base of an alkali, called lithia, which enters into the composition of the mineral *petalite*, and of several varieties of mica. It is a white metal, and little is known of its properties.

206. *Sodium*.—Sodium is the metallic base of the alkali, soda. Its combination with chlorine is common salt.

Sodium has a strong metallic lustre, and resembles silver in colour. It is so soft and ductile at common temperatures, that it may be moulded into any shape with the fingers. It fuses at 200° , and volatilizes at a red heat. Its specific gravity is .972.

It speedily tarnishes by exposure, and is instantly oxidated by water. When the water is warm, the sodium takes fire in consequence of the heat which is disengaged, and burns vividly.

207. *Potassium*.—Potassium is the metallic base of the common vegetable alkali, potassa.

It was discovered in 1807, by Sir Humphrey Davy, who decomposed potassa by means of a powerful galvanic battery, in the commencement of those celebrated investigations, which led to the discovery of the metallic bases of the other alkalies and earths.

Potassium is solid at the ordinary temperature. At 70° it is somewhat fluid, and becomes perfectly so, at 150° . At 50° it is soft like wax, and yields to the pressure of the finger. At 32° it becomes brittle. Its texture is crystalline; in colour and lustre it resembles mercury, and its specific gravity is .865. It is opaque, and conducts heat and electricity.

Its affinity for oxygen is so strong, that it rapidly oxidizes in the air, and must therefore be preserved in glass tubes hermetically sealed, or under naphtha, or some other liquid which does not contain oxygen. When heated, in the open air, it takes fire and burns with a purple flame. It decomposes water on the instant of touching it, and so much heat is disengaged, that the potassium takes fire, and burns vividly, at the same time inflaming the hydrogen gas which is disengaged.

When plunged under water, a violent reaction takes place without light, and pure hydrogen gas is evolved.

CHAPTER II.

OF COMBINATION.

208. The simple substances described in the last chapter, are the elements from which, in virtue of their mutual affinity, are formed all the various compounds in nature.

209. *Constitution of Bodies.*—A compound substance, so long as it retains the same properties, always consists of the same elements united in the same proportions. This is the essential law of chemical affinity, and is the only certain foundation of the science of Chemistry. Water, as we have seen, is a compound of oxygen and hydrogen. It is evi-

dent that there must be a limit below which the mechanical division of a drop of water cannot be carried, and that it must be possible, by repeated subdivisions, to arrive at this point. If we could by any means divide this particle, it is evident that we should obtain—not two particles of water, but those of oxygen and hydrogen, by the union of which water is formed. It is to these ultimate particles of bodies, which must necessarily exist, that we give the name of atoms. Whether they are actually the ultimate physical atoms, or lowest actual subdivision of particles, we cannot tell; but they are ultimate atoms so far as the chemist is concerned, although, in the case of the simple elements, they may consist of a number of physical atoms cohering in crystalline groups. When we speak of the atoms of a body, therefore, we must be understood as meaning the *ultimate* particles of compound bodies only.

210. *Law of Definite Proportions.*—When we attempt to combine the various simple elements, and to ascertain the proportions in which they unite, we arrive at several very remarkable results. Let us take, for example, the elements oxygen, sulphur, iron, potassium, and chlorine. Eight parts by weight of oxygen unite with 16.1 parts of sulphur, with 28 of iron, with 39.15 of potassium, and with 35.42 of chlorine, to form definite chemical compounds. Twenty-eight parts of iron combine in the same way, with 16.1 of sulphur, with 39.15 of potassium, and with 35.42 of chlorine; 16.1 of sulphur, with 39.15 of potassium, and 35.42 of chlorine; and 39.15 of potassium, with 35.42 of chlorine. The quantity of each of the other simple elements which combines with eight parts by weight of oxygen, will also combine with and neutralize the same quantity of all the others which oxygen does; so that we are thus furnished with a series of numbers, representing the proportions in which the simple elements combine,

and therefore, with propriety, called their *combining numbers* or their *chemical equivalents*.

211. *Law of Multiple Proportions*.—In many instances, there are several combinations in different proportions of the same elements. Thus there are five compounds of oxygen with nitrogen, and two with iron. In all such cases the proportions of the several elements vary by a very simple law. It commonly happens that one only of the elements is increased in quantity, and this always increases by a simple multiple. Thus in the several compounds of oxygen and nitrogen, that in which there is the least oxygen consists of 8 parts by weight, of oxygen and 14.15 of nitrogen. The second consists of 16, the third of 24, the fourth of 32, and the fifth of 40 parts of oxygen, to the same quantity 14.15 of nitrogen. On the other hand, the first combination of iron with oxygen, contains 28 of iron and 8 of oxygen; and the second $28 \times 2 = 56$ of iron, and $8 \times 3 = 24$ of oxygen. The lowest of these combinations must be conceived to consist of a chemical atom of oxygen, united with one of nitrogen, or of iron; while the others contain 2, 3, 4 or 5 atoms of oxygen united with one of nitrogen, or 3 atoms of oxygen with two of iron.

The views above given of the definite nature of chemical compounds, receive the strongest confirmation from the laws which regulate the union of gases. All the known gases combine either in equal volumes, or in volumes which are in the simple ratio of 1 to 2, 1 to 3, 1 to 4, 2 to 3, 2 to 5, &c., nor can they be made to unite in any intermediate fractional ratio. For example, 50 measures of oxygen unite with 100 measures of hydrogen to form water; 100 measures of nitrogen unite with 50 of oxygen to form protoxide of nitrogen, and with 250, to form nitric acid.

212. *Equivalent Numbers*.—These combining numbers represent not only the composition of these

compounds, but the proportions in which they themselves unite to form more complex combinations. Thus five atoms of oxygen and one of nitrogen form the substance called nitric acid, the combining number of which is the sum of the weights of its elements, that is $5 \times 8 + 14.15 = 54.15$. One atom of oxygen, and one of potassium, form the substance called potassa, the combining number of which is 47.15; and one atom of nitric acid and one of potassa, unite to form the salt called nitrate of potassa, the atomic weight or combining number of which is $54.15 + 47.15 = 101.3$. This law applies to the most complex combinations. The combining or atomic weight of any substance whatever, is the sum of the weights of the simple atoms that compose it; and these numbers, or their multiples, express in all cases, the proportions in which the bodies combine.

213. The lowest combination of oxygen with iron, is in the proportion of 8 to 28, and the next highest, of 12 to 28. If we regard 8 as the weight of an atom of oxygen, 12 must represent an atom and a half, which is manifestly an impossible quantity. It is found likewise, that when this oxide enters into combination, its combining number is 80, and not 40; and we must therefore suppose that it is formed of three atoms of oxygen and two of iron.

214. There is a combination of sulphur and oxygen (the hypo-sulphurous acid) in the proportions of 16.1 to 8, and of which the combining number might be supposed to be 24.1. It is found that this acid unites with a single atom of oxides to form salts, and that its combining number is always 48.2, and not 24.1. It is therefore inferred, that it is a compound of two atoms of each of its elements. These examples prove that the actual combining number of a body cannot be ascertained from mere theory, without ascertaining the fact from experiment.

215. *Proximate and Ultimate Elements.*—It is easy to determine the proportions of the simple ultimate elements that enter into the composition of a complex body. It is far otherwise when we attempt to ascertain the nature of the proximate elements, as they are termed, of these compounds. What, for example, is the true constitution of the salt called nitrate of potassa? It is formed, as we have seen, by the union of nitric acid with potassa; and we may conceive these to be its proximate elements; or we may imagine the six atoms of oxygen, the atom of nitrogen, and that of potassium which it contains, to be combined in various other ways, so as to render it, theoretically, a substance belonging to an entirely different class. So, likewise, there is a salt which contains six atoms of oxygen, one of nitrogen, and one of lead. Now we may conceive this salt to be the nitrate of the protoxide of lead, ($\text{Pb O} + \text{NO}_3$), or the nitrite of the deutoxide, ($\text{PbO}_2 + \text{NO}_2$), or it may be, as is now supposed by many, a combination of metallic lead, with a radical consisting of one atom of nitrogen and six of oxygen ($\text{Pb} + \text{NO}_6$). The speculations into which this uncertainty has led, constitute one of the most subtle and refined investigations in the science, and will be hereafter reverted to.

216. *Isomerism.*—This subject has presented itself to chemists in another aspect. Several substances have been discovered, possessing properties so different from each other, as to create no suspicion of their identity. Yet analysis has proved them to consist of the same ultimate elements united in the same proportions. It might be thought at first sight, that a single fact of this kind would unsettle the science, by destroying the value of sensible properties as a test of identity of composition.

A closer examination shows that it is a natural result of a complex combination. The ultimate elements must be capable of forming various simpler

compounds, which are themselves the proximate elements of the bodies into which they enter, and thus, under an apparent identity, conceal an essential difference of composition. This resemblance is called *Isomerism*, and those bodies are said to be isomeric, the sensible properties of which differ, while their ultimate composition and combining numbers are the same.

217. There is a compound of carbon and hydrogen in their atomic proportions, but which consists undoubtedly of two atoms of each of its elements. This is the olefiant gas of chemists, and its combining number is $6.12 + 1 \times 2 = 14.24$. There is another substance called etherine, entirely distinct in its properties, composed of the same elements in the same proportions; but of which the combining number is found to be 28.48; being composed of four atoms of each of its elements. There are many examples of the *modified* isomerism, of which this is an instance.

218. *Atomic Weights of the Elements*.—The following table contains the names and atomic weights of the simple elements, and the characters by which they are expressed in designating their various compounds. The numbers are taken from the last edition (1841) of Turner's Chemistry, by Liebig and Gregory.

<i>Elements.</i>	<i>Symbols.</i>	<i>At. Num.</i>	<i>Elements.</i>	<i>Symb.</i>	<i>At. N.</i>
Oxygen,	O.	8.	Phosphorus,	P.	15.7
Chlorine,	Cl.	35.42	Selenium,	Se.	39.6
Iodine,	I.	126.3	Tellurium,	Te.	64.2
Bromine,	Br.	78.4	Arsenic,	As.	37.7
Fluorine,	F.	18.68	Antimony,		
Nitrogen,	N.	14.15	(Stibium,) St.		64.6
Hydrogen,	H.	1.	Chrome,	Cr.	28.
Carbon,	C.	6.12	Vanadium,	V.	68.5
Boron,	B.	10.9	Molybdenum,	Mo.	47.7
Silicon,	Si.	22.5			

<i>Elements.</i>	<i>Symbols.</i>	<i>At. Numb.</i>	<i>Elements.</i>	<i>Symbols.</i>	<i>At. Numb.</i>
Sulphur,	<i>S.</i>	16.1	Tungsten, (Wolfram,)	<i>W.</i>	99.7
Columbium, (Tantalum,)	<i>Ta.</i>	185.	Zinc,	<i>Zn.</i>	32.3
Uranium,	<i>U.</i>	217.	Cadmium,	<i>Cd.</i>	55.8
Cobalt,	<i>Co.</i>	29.5	Ferrum,	<i>Fe.</i>	28.
Manganese,	<i>Mn.</i>	27.7	Cerium,	<i>Ce.</i>	46.
Titanium,	<i>Ti.</i>	24.3	Aluminium,	<i>Al.</i>	13.7
Stannum,	<i>Sn.</i>	57.9	Yttrium,	<i>Y.</i>	32.2
Aurum,	<i>Au.</i>	199.2	Glucinium,	<i>G.</i>	26.5
Platinum,	<i>Pl.</i>	98.8	Thorium,	<i>Th.</i>	59.6
Argentum,	<i>Ag.</i>	108.	Zirconium,	<i>Zr.</i>	33.7
Palladium,	<i>Pd.</i>	53.3	Magnesium,	<i>Mg.</i>	12.7
Rhodium,	<i>R.</i>	52.2	Calcium,	<i>Ca.</i>	20.5
Osmium,	<i>Os.</i>	99.7	Strontium,	<i>Sr.</i>	43.8
Iridium,	<i>Ir.</i>	98.8	Barium,	<i>Ba.</i>	68.7
Nickel,	<i>Ni.</i>	29.5	Lithium,	<i>L.</i>	6.
Hydrargyrum,	<i>Hg.</i>	202.	Sodium,		
Bismuth,	<i>Bi.</i>	71.	(Natrium)	<i>Na.</i>	23.3
Plumbum,	<i>Pb.</i>	103.6	Potassium,		
Cuprum,	<i>Cu.</i>	31.6	(Kalium.)	<i>K.</i>	39.15

The numbers above given are entitled to as much confidence as the state of experimental science will warrant; although slight differences will arise in calculating the result of different analyses. The only variations which it is important to notice, are, that Berzelius, and other Continental chemists, supposing the same volume of all simple gases to consist of the same number of atoms, regard the atomic weight of hydrogen, nitrogen, chlorine, bromine, iodine, and fluorine, as only half that above stated, and give the atomic constitution of bodies, at double the number of atoms of these elements, which the English chemists assign. Other chemists, from theoretical views, double the atomic numbers of phosphorus, arsenic, and antimony, and halve that of Mercury.

219. *Chemical Symbols.*—There are two methods of using the symbols in the preceding table.

The first, or algebraic mode, will be readily understood by a few examples. Thus the several compounds of nitrogen and oxygen are designated by $N+O$, $N+2O$, $N+3O$, $N+4O$, $N+5O$, the figures denoting then umber of atoms. Thus $Fe+O$, and $2 Fe+3O$, denote the protoxide, and sesqui-oxide of iron. The formula, $(N+5O)+(2 Fe+3O)$, denotes the nitrate of the sesqui-oxide of iron, and $(K+O)+2 (S+3O)$, the bisulphate of potassa. The advantages of the algebraic method are its simplicity and exact representation of facts. It is, however, inconveniently long, and Berzelius has introduced several modifications which are recommended by their brevity. He expresses the degree of oxidation by dots placed over the symbol, and the number of atoms of sulphur by commas placed in like manner, and he represents two atoms of base by a dash, through or beneath its symbol. Thus the following algebraic symbols $N+O$, $N+2O$, $N+3O$, $N+4O$, $Fe+S$, $Fe+2S$, $2 Fe+3O$, would be represented by Berzelius thus: $\overset{\cdot}{N}$, $\overset{\cdot}{N}$, $\overset{\cdot}{N}$, $\overset{\cdot}{N}$, $\overset{\cdot}{Fe}$, $\overset{\cdot}{Fe}$, and $\overset{\cdot}{Fe}$.

220. A more convenient method, which is now becoming general, and which will be adopted in this volume, will be best understood by examples. The symbols are written without any intervening sign, and the number of atoms of each element is designated by figures placed at the foot, and to the right of the proper symbol. Thus NO , NO_2 , NO_3 , NO_4 , NO_5 , $Fe O$, $Fe_2 O_3$, designate the several oxides of nitrogen and iron above mentioned. The proper numeral is prefixed to designate the number of the atoms of these compounds, which unite to form compounds of a secondary order, and the sign of addition, or a simple comma connects the symbols; as $KO+2SO_3$, KO , $2SO_3$ for the bi-sulphate of potassa.

There are many compounds of a very complex

constitution, the occurrence of which as an element of other bodies is so frequent, that a distinct symbol is used to express them. Thus, for instance the composition of Benzule is $C_{14} H_8 O_2$, and its symbol is Bz. Water, ammonia, and other compounds, which enter extensively into combination, have also distinct symbols, which will be noticed in the several cases as they occur.

221. *Chemical Nomenclature.*—The rapid advances which the science of chemistry has made within the last sixty years is undoubtedly due, in a great measure, to the nomenclature framed by the illustrious Lavoisier, and his associates, Guyton Morveau, Berthollet, and Fourcroy. It is the most beautiful example of an universal philosophical language, which has ever been presented to the world, and it has greatly aided the diffusion of accurate chemical knowledge, by the perfect precision and self-explaining character of its terms.

Even in those cases in which the sagacious framers of this language fell into theoretical errors, from the imperfect state of chemical science in their day, the principles which guided them, furnish us with the means of rectifying their errors and supplying their defects.

222. The following is a sketch of the nomenclature at present in use.

The bi-elementary compounds are arranged in genera named from the electro-negative element, by adding to it the termination *ide* or *uret*. Thus the compounds oxygen, chlorine, bromine, iodine and fluorine, are called oxides, chlorides, bromides, iodides, and fluorides, and the compounds of carbon, sulphur, phosphorus, hydrogen, are called carburets, sulphurets, phosphurets, and hydrogurets.

As the same substances unite in more than one proportion, the various compounds are designated by terms explanatory of their composition. A com-

pound formed by the union of an atom of each of its elements, is called a protoxide, a proto-chloride, &c., or simply an oxide, chloride, &c., as the case may be. If it consists of two, three, or four atoms of the electro-negative element united with one of the electro-positive, it is called deuto or bi-chloride, deutoxide or binoxide, ter-chloride, ter-oxide, quadrochloride, quadroxide, &c. The combination which contains the greatest portion of the electro-negative element, is also called a per-oxide, per-chloride, &c.

If the compound contains three atoms of the electro-negative and two of the electro-positive element, it is called a sesqui-oxide, sesqui-chloride, &c.

If it contains one atom of the electro-negative element, united with two, three, or four atoms of the electro-positive, it is called a *di*-chloride, tri-chloride, &c.

It has not been deemed necessary to extend this system of nomenclature further than is here pointed out. When bi-elementary combinations of a greater number of atoms do however occur, they may be designated by fractional numbers in which the numerator represents the electro-negative, and the denominator the electro-positive element, as, for example, the $\frac{4}{5}$ oxide of iron would designate a compound of 4 atoms of oxygen with 5 of iron.

223. These bi-elementary compounds are themselves elements of a secondary order, divided into acids and bases, and forming, by their union with each other, several distinct and peculiar classes of compounds, the most important and extensive of which is that of the *neutral salts*.

224. *Acids*.—An acid, in the meaning attached by Lavoisier, and his associates, to that term, is an oxide having a sour taste, reddening vegetable blues, and combining with the alkalies and earths, so as to form a transparent crystalline compound, termed a salt. But many substances which possess all these pro-

perties contain no oxygen, and others which form neutral salts have not a sour taste and do not redden vegetable blues. It has therefore become necessary to extend the meaning of the term acid, and to include in the class all those electro-negative compounds which combine with the electro-positive compounds of the same genus, and form crystalline compounds analogous to the salts.

The simple electro-negative elements, oxygen, chlorine, iodine, bromine, fluorine, sulphur, and selenium, combine with the elements which are electro-positive in relation to them, forming compounds which are either electro-negative or electro-positive. The former constitute, as has been said, the class of acids.

Instead therefore of oxygen being, as Lavoisier supposed, the sole principle of acidification, we have oxygen acids, chlorine acids, iodine acids, &c., each constituting a separate genus of acids. It was early discovered that the same substance formed more than one acid, as, for example, there are two acids of sulphur, two of nitrogen, and two of phosphorus. In order to distinguish these from each other, Lavoisier designated that acid which contains the smallest quantity of oxygen, by adding to the name of the base the termination *ous*, and the other by the termination *ic*, as sulphurous, nitrous, phosphorous, sulphuric, nitric and phosphoric acids. Acids have since been discovered intermediate between the above, or of still lower degrees of oxygenation. These acids have been designated by prefixing the term *hypo* to the name of the acid following them in the series of oxygenation. Thus hypo-nitrous, and hypo-nitric acids, contain less oxygen than the nitrous, and nitric acids, and immediately precede them in the series of oxygenation.

225. While it was supposed that oxygen was the sole acidifier, the above nomenclature was sufficient

for all the cases that could occur. But as there are other acidifiers than oxygen, each forming acids with the same base, it has become necessary to designate the acidifying principle. Hydrogen, for example, forms acids with chlorine, iodine, bromine, sulphur, &c., which are designated by the terms chloro-hydric, iodo-hydric, bromo-hydric, and sulpho-hydric acids. Carbon is another example of this, as it is acidified both by oxygen and sulphur. The two acids are therefore to be called the oxy-carbonic and the sulpho-carbonic acids; but inasmuch as the oxygen acids are the most numerous and abundant, and as long use has familiarized us to their name, we seldom prefix to them the term oxy, but always understand an oxygen acid to be spoken of when the name of the base only is given.

226. *Bases*.—The electro-positive bi-elementary compounds are classed together under the name of bases, and possess the common property of forming salts by combining with, and neutralizing the acids of the same genus; that is to say, the electro-positive oxides, and sulphurets, combine with electro-negative oxides, and sulphurets, forming oxygen, and sulphur salts.

227. *Salts*.—Chlorine, iodine, bromine and fluorine, combine with the metals, and these binary compounds are genuine salts. Berzelius distinguishes them by the name of *haloid salts*. The bearing of this fact upon the true theory of the oxygen salts will be hereafter noticed. At present it will suffice to give the Levoisierian view of their constitution.

As Lavoisier knew of but one class of acids, he was acquainted with but one class of salts, and in framing his nomenclature did not provide for the designation of any but oxy-salts.

Each distinct acid forms and gives its name to a peculiar genus of salts. The salts formed by the acids whose names terminate in *ous* are designated

by the termination *ite*. Thus the salts formed by the sulphurous, phosphorous, nitrous, and arsenious acids, are called *sulphites*, *phosphites*, *nitrites*, and *arsenites* of the several bases; as the sulphite of iron, copper, &c. The salts formed by the acids whose names terminate in *ic*, are designated by the termination *ate*; thus the salts formed by the sulphuric, carbonic, nitric and arsenic acids are termed the *sulphates*, *carbonates*, *nitrates*, and *arsenates* of their several bases, as the sulphate of iron, copper, &c.

228. The number of atoms in the electro-negative element of a salt is designated by the Latin numerals. Thus the terms *bi*, *ter*, and *sesqui* sulphate of iron, denote a combination of 2, 3, and $1\frac{1}{2}$ atoms of sulphuric acid, with an atom of oxide of iron. As many of the metals form more than one compound with electro-negative elements, and thus furnish more than one saline base, it is necessary to designate these in the nomenclature of the salts. This can generally be done with great accuracy by using the terms *proto*, *deuto*, and *per*, to designate the first, second, and highest combinations of the metals, with an electro-negative element. Thus the *proto-sulphate* of iron, and the *per-sulphate* of iron, denote the combination of sulphuric acid with the protoxide, and per-oxide of iron; and the *bi-proto-sulphate*, and the *bi-per-sulphate* of iron denote the combination of two atoms of the acid with an atom of the respective bases.

229. When we wish to designate the class to which a salt belongs, we must prefix the name of the class; thus, for example, the *oxy-sulphate* of iron denotes a salt in which the teroxide of sulphur (sulphuric acid) is combined with the protoxide of iron.

A sulphur salt is, in the same manner, the combination of an electro-negative sulphuret, with an electro-positive one. The *bi-sulphuret* of carbon, and

the per-sulphuret of arsenic, are sulphur acids, whose correct names are sulpho-carbonic, and sulph-arsenic acids, and their combinations with electro-positive sulphurets, are the sulpho-carbonates and sulph-arsenates.

230. *Electrolytic Decomposition.*—It is observed that when any compound substance whatever is decomposed in the voltaic circuit, one of its elements is separated at the positive, and the other at the negative electrode. It is therefore inferred, that all substances that enter into combination are in opposite electrical states, one of them being negative and the other positive. The laws which regulate the chemical action of the voltaic battery, are therefore calculated to throw much light on the nature of chemical forces.

231. It has been ascertained by Dr. Faraday, that no substance that is a non-conductor of electricity is either capable of exciting electrical currents in the battery, or susceptible of electro-chemical decomposition; or, in other words, this cannot take place unless an electrical current is transmitted through the substance.

As the solidity of a body prevents that mobility of its particles which is necessary to its decomposition, and as no electrical current can pass in the voltaic circuit without decomposition, it is evident that the exciting body in a circuit must be in a fluid state. Accordingly it is found that ice will not conduct the electric current and is not susceptible of decomposition, and the observation holds true of all other solids that are capable of exciting the voltaic battery in their liquid state.

232. Faraday further ascertained that of all the various combinations of any two elements, one only is susceptible of electro-chemical decomposition, and that this in all cases consists of an equal number of atoms of each element. Bodies susceptible of elec-

tro-chemical decomposition are called *electrolytes*, which are therefore in all cases *binary compounds*. To *electrolyse* a body, is to decompose it by the direct action of electricity; the name being compounded of *ηλεκτρον*, and *λυω*, to loose.

233. The elements of an electrolyte are called *ions*, from *ιον*, going. Anions are those ions which appear at the anode, and *cations* those which appear at the cathode.

It is ascertained that *most*, and it is probable that *all*, of the simple elements are ions. Owing to the difficulty of obtaining liquid electrolytic compounds of nitrogen, carbon, phosphorus, boron, silicon, and aluminium, these elements have not yet been proved to be *ions*.

An ion is not necessarily a simple body, for any compound substance forming a binary compound with another becomes an ion. Those neutral salts, for example, which contain an atom of acid and an atom of alkali, are all electrolytes, and their elements ions, although none of the acids are themselves electrolytes.

234. Many substances not electrolytes are themselves decomposed by what is called the secondary action of the battery. The elements of the decomposed electrolyte being set free, are presented in their nascent form to the adjacent bodies, a circumstance peculiarly favourable to chemical action. Nitric acid is thus decomposed by the hydrogen of the water which is set free; and nitrous acid and water are formed. In many cases the electrode itself is attacked, as when zinc, for example, is used, it is oxidated by the nascent oxygen of the water.

In experiments with the voltaic battery this secondary action of the pile must be carefully separated from its primary and direct action. The former adds nothing to the quantity or intensity of the electrical currents set in motion by the latter.

235. *The Volta Electrometer.*—It has been clearly ascertained by Faraday, that these currents are an exact measure of the quantity of the electrolytic action of the pile. By using electrodes of platinum and pure zinc, he obtained a battery in which there was no chemical decomposition, except that which was owing to electrolytic action, and he was thus enabled to ascertain its exact amount. By conducting the electrical currents thus produced through a vessel of water, and collecting the gases resulting from its decomposition, he proved that the quantity of water decomposed by the electrical current was precisely equal to that, the decomposition of which, in each cell of the battery, set the current in motion. He also discovered that the same current may be made to perform any number of decompositions, and was thus enabled to submit various compounds at the same time to the action of the same current, and proved that the quantities thus decomposed were always in the exact ratio of their atomic weight. The current which decomposed 9 grains of water ($\text{HO}=9$), also decomposed 230 grains of iodide of lead ($1 \text{ iodine}=126.3+1 \text{ lead}=103.6$) and 143.42 grains of chloride of silver ($1 \text{ chlorine}=35.42+1 \text{ silver}=108$); that is to say, the electricity evolved by the electrolytic decomposition of an atom of water is exactly sufficient to decompose an atom of any other electrolyte. By the aid of a simple instrument called the *volta electrometer*, which consists of platinum electrodes inserted in a graduated glass tube, in which the gases evolved by the decomposition of water are collected, he obtained a measure of the quantity of electricity that had passed through the voltaic circuit in a given interval of time. We are thus furnished with a means of measuring electricity by its chemical agencies, as accurately as we measure the relative degrees of heat by the thermometer.

236. Identity of Chemical and Electrical Forces.

—It appears probable that when a compound is decomposed by electricity, the positive electricity of the current combines with the negative electricity of the negative element, and the negative electricity of the current with the positive electricity of the positive element. The forces which held the two elements together are thus neutralized, and the inference seems irresistible that they must be the antagonist forces, or, in other words, the opposite electricities of those by which they are thus counteracted. If, therefore, the elements that form compound bodies are held together by electrical forces, and are separated when these forces are neutralized by an equal quantity of the opposite electricity, it is evident that the same quantity of electricity must be the agent in holding together an atom of any binary compound whatever, for an atom of such compound is always decomposed by the quantity of electricity that is evolved in the electrolytic decomposition of an atom of any other binary compound.

237. Causes of the efficacy of the Battery.—As no electricity can pass in the voltaic circuit, except what is due to electrolytic action, it follows that the quantity circulated in a battery, is no greater than that evolved by the weakest cell of the battery, and that this is no more than would be evolved by a single pair of similar plates. However powerful the other cells may be, all the electricity evolved by them, beyond what its own chemical action transmits, is arrested by the weaker cell. The superior efficiency of the compound battery appears to be owing to an increase in the *intensity* or energy of propulsion, and not in the quantity of the electrical current.

238. Chemical affinity elective.—The chief character by which chemical affinity is distinguished from other kinds of attraction, is that which procured for it one of its earliest names, viz. *elective affinity*.

If lime and magnesia be placed in contact with

chlorohydric acid, the acid will dissolve the lime before it acts on the magnesia. So likewise if sulphuric acid and a solution of the alkali soda be poured together, they will combine and form a compound having neither acid nor alkaline properties. If a solution of the alkaline earth baryta be now added, the sulphuric acid will leave the soda and unite with the baryta; this new combination will be precipitated as a white powder; and we say that the sulphuric acid has a stronger affinity for the baryta than for the soda. Trials of this kind determine the substances which appear to have the strongest affinities for sulphuric acid; and very useful tables of elective affinity are thus formed, in which the relative affinity for the substance at the head of the column, is indicated by the order in which the substances are enumerated.

239. *Double elective affinity.*—If solutions of acetate of lead and of sulphate of zinc be poured together, two new salts will be formed, sulphate of lead and acetate of zinc. The interchange is commonly said to be owing to *double elective affinity*, as the former are said to be cases of *simple elective affinity*. In the instance now given, the sulphuric acid has a stronger affinity for the oxide of lead than the acetic acid has; and it will therefore of itself decompose the acetate of lead. But there are instances of double decomposition in which this is not the case. For example, let the affinity of the acid A for the alkali C, be represented by 11, and its affinity for the alkali D, by 12. If then the affinity of an acid B for C, be represented by 8, and for D, by 11, it is evident that the combination of A with D, the force of which is 12, could not be disturbed either by the alkali C, nor by the acid B, the attraction, of which for A and for D is each represented by 11. If, however, the compound of B with C, the force of which is 8, be added to that of A with D, decomposition will

take place; for the sum of the *quiescent affinities*, as they are termed, which tend to maintain the bodies as they are, is $8+12=20$; and the sum of the *divellent affinities*, or those which tend to separate them and form new compounds, is $11+11=22$.

240. It is a consequence of the law of chemical equivalency, that in all cases of double decomposition, the resulting compounds are exactly neutralized, and that no uncombined acid or alkali remains in the solution. A few apparent exceptions will be explained in the cases where they occur.

241. It is difficult to ascertain what decompositions and combinations take place in mixed solutions, where all the compounds that can be formed are soluble. Sulphuric acid will separate the last particle of boracic acid from its combination with soda, although the whole of it remains in solution. And yet it seems probable that two soluble salts generally co-exist in proportions regulated by their respective affinities.

242. If one of the resulting salts be insoluble, it will in every case, be formed. If any one of the salts A D, for instance, be less soluble than the other, and the solution be evaporated until this salt crystallize so as to diminish its relative proportion, an additional portion will be formed; and by continuing the process all the acid will combine with the alkali D. The salts which are obtained by the evaporation of dilute solutions are therefore not necessarily those which it originally contained; for new combinations will take place, as we pass the point of saturation of the several salts whose elements thus co-exist in the solution.

243. *Change of properties by Combination.*—The combination of elements that differ much in their electrical relations, that is to say, one of which is highly negative to the other, is always accompanied with so great a change of properties, that the result-

ing compound must be placed in a different class and be called by a new name. When the elements approximate to each other, in their general character and electrical condition, there are many cases in which the resulting compound appears merely to blend or slightly modify the properties of its elements, and to belong to the same class of bodies in a philosophical arrangement. Thus the chloride of iodine, the iodide of bromine, and the sulphuret of phosphorus, are neither acid nor alkaline, but are supporters of combustion, or combustible like their elements. The metals eminently possess this character in their combinations with each other; and the compounds, or *alloys*, as they are termed, formed by their fusion and intermixture, acquire no new generic qualities, but possess all the properties of metals.

244. *Extrication of Heat and Light.*—The combination of the simple elements, which differ greatly in their electrical relations, is in general accompanied with the copious extrication of heat and light, the source of which is not known.

The most common instance of this is the combustion of inflammable bodies in oxygen gas. When a portion of the body is raised to the temperature at which combination takes place, the heat that is extricated is sufficient to raise an additional portion to the same temperature, and thus the combination goes on until the whole body is consumed. Where the combustible is a compound, which is resolved at this temperature into gaseous elements, it burns with a flame. These results are beautifully shown in the burning of a common oil lamp.

245. In the case of gunpowder, the inflammation is propagated so rapidly through the whole mass, and the volume of the gaseous products of the combustion thus suddenly formed is so great, as to render that substance one of the most tremendous engines of destruction known to man.

246. The union of binary compounds with each other is seldom accompanied with the extrication of much heat or light, and the more complex the body, with the greater facility does it in general change its combinations.

247. *Force of Chemical Union.*—The stability of chemical compounds varies exceedingly. The elements which are most firmly united are those forming binary compounds, and differing greatly in their electrical conditions. The most intense heat and the most powerful re-agents are scarcely able to separate the elements of some of the chlorides and oxides.

248. In general the ease with which decomposition takes place, increases with the increase of one of the elements. Thus nitric acid is much more easily decomposed than the deutoxide of nitrogen; and the metallic per-oxides readily yield up the second and third atoms of oxygen, while they part with difficulty with the first.

249. *Molecular agitation a cause of Decomposition.*—On the other hand the per chloric acid, which contains 7 atoms of oxygen, is decomposed neither by hot chlorohydric acid, nor by organic substances; while the protoxide of chlorine is one of the most unstable compounds in existence, being decomposed by the molecular agitation caused by mere expansion.

This instability of composition is still more remarkable in the fulminating salts of the metals. The slight friction of a grain of sand against a single particle of fulminating silver, will be sufficient to cause a new arrangement of its elements, which instantaneously assume a gaseous form; and the impulse thus given is propagated through the whole mass with the rapidity of lightning.

250. In these cases the forces which hold the atoms together are so slight, the *divellent* so nearly balance the *quiescent* affinities, that the chemical equilibrium

seems to be maintained by the mere vis inertiae of the particles. Whatever cause disturbs this and sets the atoms of a single particle in motion, decomposes that particle, motion is communicated to the adjoining, and the decomposition is propagated with more or less rapidity through the whole mass.

251. There are cases of combination in which the quiescent affinities are so nearly balanced by the divellent, that the presence of a second body may effect the decomposition of the first, while at the same time the molecular agitation, which takes place so disturbs the equilibrium of the particles in the decomposing body, and the heat generated is so great that it also is decomposed. In no other way can we understand what takes place when oxide of silver is added to deutoxide of hydrogen. The latter is rapidly decomposed, oxygen escapes, and water and metallic silver remain.

252. Examples of this law are of constant occurrence. If a dilute solution of a salt of potassa be carefully added to one of tartaric acid, and the mixture remain perfectly quiet, no change takes place. But if it be briskly agitated, the motion thus communicated to the particles is sufficient to destroy the equilibrium, and produce a new arrangement, and crystals of bi-tartrate of potassa are immediately formed. These cases somewhat resemble the forced equilibrium of the particles of glass in what are called *Prince Rupert's Drops*. These are formed by letting drops of melted glass fall into cold water. The external particles are at once solidified and their contraction forces the still soft and yielding interior mass, into a smaller space than the gradual cooling of the whole would have allowed it to occupy. It is therefore kept in a state of tension, which acts as soon as the external force is removed; so that if the least fragment be broken from the small end, the whole drop is shattered into fragments.

253. *Influence of the presence of a third body.*—There are cases in which an influence not sufficiently understood is exerted by the presence of a third body. Zinc slowly decomposes water, and concentrated sulphuric acid does not attack zinc; yet when the three are mixed, the water and the zinc are acted on with the greatest energy. In this case the sulphuric acid probably acts by dissolving the thin film of oxide, which forms on the surface of the zinc, and keeps the metal bright, thus promoting the decomposition of the water, which is further aided by the heat, generated by the chemical action.

254. Platinum in a state of minute division may be immersed in boiling nitric acid, without the slightest chemical action; while its alloy with silver is readily dissolved. In this case the silver is oxidated by the decomposition of the nitric acid, and the platinum, in the act of being set free from its combination with the silver, being in what is called its nascent state, also combines with oxygen and forms a salt with nitric acid.

255. Many substances which in their ordinary state, exhibit feeble traces of affinity for other bodies, and which can scarcely be made to unite with them, readily enter into combination, when they are presented in what is called their *nascent state*, that is to say, when existing combinations are decomposed and elements, capable of uniting into new compounds are disengaged. It is with extreme difficulty for instance, and but in small quantities, that nitrogen can be directly combined with hydrogen gas. Yet ammonia, which is their most stable compound, is always copiously formed when animal bodies which contain them both are decomposed.

256. The combination of gases which have an affinity for each other, is greatly promoted by the presence of certain solids. Oxygen and hydrogen, may be kept together in a glass vessel, for an indefinite time, without showing any disposition to

unite. Yet if a piece of platinum foil be placed within the vessel, drops of water will make their appearance on the sides, and the two gases will gradually combine together. This combination takes place so rapidly when the platinum is in a finely divided state, such as is obtained by precipitation, that the metal becomes red hot, and the gases explode. By the same agency, the combination of many other gases may be effected. Many porous bodies, such as powdered glass, pumice stone, charcoal, &c., possess this property at the temperature of 200°, or 300°.

257. The union in these cases seems to be effected by an adhesion of the gaseous particles to the surface of the solid body, similar to that of certain liquids to solids, so that their mutual affinities are brought into play. The phenomenon appears to confirm the theory of Dalton, that the repulsive force of the particles which constitutes a gas, like the cohesive force which constitutes a solid, obtains only between homogeneous particles, and that the different gases so far from repelling, are mutually indifferent to, each other.

258. *Absorption of gases by Solids.*—In other cases the adhesion above spoken of causes a copious absorption, analogous to liquefaction. Thus a cubic inch of charcoal will absorb 90 cubic inches of ammoniacal gas, which it gives out again when heated. We cannot but conceive the gas in this case, to be held adhesively in a liquid state, amidst the pores of the charcoal.

259. *Solvent power of Fluids.*—The most simple instance of the exercise of chemical attraction is afforded by the admixture of two fluids, such as water and sulphuric acid, or water and alcohol; or by the solution of a solid in a fluid, as of sugar in water, or camphor in alcohol.

In some cases of simple mixture of fluids, and of

the solution of solids in fluids, the proportions in which they unite appear to be unlimited. Water and alcohol, gum and water, and camphor and alcohol, for example, will combine in all proportions. There are other cases in which the union takes place in all proportions up to a certain limit. One hundred grains of water, for example, will dissolve any quantity of sea-salt which does not exceed forty grains. Its solvent power then ceases, and it is said to be saturated. The solvent power of a liquid is in most cases, though not always, increased by heat. Substances which unite in unlimited proportions, or in all proportions up to a certain limit, give rise to compounds which have this common character, that their elements are united by a feeble affinity, and preserve, when combined, more or less of the properties which they possess in their separate state.

260. *Influence of cohesion.*—Solid bodies seldom act upon each other, as chemical affinity is exerted only at insensible distances, and the particles of solids do not come within the sphere of each other's attraction. Fluids oppose no obstacle to the action of chemical affinity, and whether a solid is rendered liquid by increasing the heat, or by dissolving it in some menstruum, it is in this state that chemical affinity acts with its whole energy. Bodies which do not unite with each other when they are intimately mixed in a fluid state, possess little or no affinity for each other.

The fluidity of one of the bodies is often sufficient for effecting chemical union, as in the case of sugar, or salt, and water.

261. *Influence of Elasticity.*—When an elastic fluid enters into the composition of a solid or liquid body, its elasticity tends to counteract the effect of chemical affinity, and the compound will be decomposed by a third body, having actually a weaker affinity for the second than its own.

The volatility of certain substances affords a ready method of separating them from their combinations. Alcohol and water have an affinity for each other, but the former is volatile at a much lower temperature than the latter, and may be almost entirely separated from it by heat.

262. Change of Density.—Two bodies rarely occupy, after combination, the space which they took up separately. In general, the density of the compound exceeds the mean density of its elements. For example, 100 measures of water and an equal quantity of sulphuric acid, or of alcohol, do not occupy 200 measures. The alloys of metals generally have a greater density than the mean of the simple metals of which they are formed.

This is still more remarkably the case with the gases. Many gases combine without undergoing any change of volume. But in the greater number of cases a very great condensation occurs, and the volume of the resulting compound bears a very simple ratio to the volume of its elements; this will sufficiently appear from the following table, in which all the substances are supposed to be in the gaseous state.

Volumes of Elements.		Volume of resulting compound.
100 N+300 H	yield	200 ammonia,
50 O+100 H	"	100 water,
50 O+100 N	"	100 protoxide of nitrogen,
100 S+600 H	"	600 sulphohydric acid,
100 S+600 O	"	600 sulphurous acid,
100 Cl+100 H	"	200 chlorohydric acid,
100 I+100 H	"	200 iodohydric acid,
100 Br+100 H	"	200 bromohydric acid,
100 O+100 N	"	200 deutoxide of nitrogen.

263. Change of Form.—A change of form frequently accompanies chemical combination. The combination of gases may give rise to solids or liquids; solids sometimes become liquid, and liquids

solid. When in consequence of chemical combination, solids or liquids suddenly become gases, detonation takes place; when a gas and a liquid are formed, the escape of the former through the latter gives rise to effervescence, and when a solid and a liquid are formed, the deposition of the former is called precipitation.

All these changes of density and form in chemical combination are accompanied with a change of temperature, the causes of which have been explained in the chapter on caloric.

264. *Change of Colour.*—Chemical action is often accompanied with change of colour, and no law regulating this change has yet been discovered. For example, iodine, the vapour of which has a violet colour, forms a red compound with mercury, a yellow compound with lead, and colours starch blue.

265. Such are the principal laws which govern chemical combination. In the chapter on salts, and in that on compound radicals, the subject will be resumed, and the principles which regulate the constitution of highly complex bodies, will be further developed.

In treating of compound substances it will be convenient first to consider the bi-elementary compounds, ranging them into genera, under the heads of their electro-negative element.

CHAPTER III.

BI-ELEMENTARY COMPOUNDS.

266. The compounds which are formed by the union of two simple elements may be designated as binary compounds of the first order. They contain several very natural groups, such as acids, alkalis, earths, the haloid salts, and alloys.

267. Principles of Classification.—The elements themselves, as has been stated, may be arranged according to their electric relations; with oxygen, the most highly electro-negative, at one end of the scale, and potassium, the most highly electro-positive at the other. If such a table could be formed with entire accuracy, each element would be electro-negative to all below and electro-positive to all above it in the scale.

The binary compounds may be classed in genera according to their electro-negative element. The most obvious arrangement would be according to their sensible properties as acids, alkalies, &c.; but as these sensible qualities depend upon, and are controlled by their electrical relations, the latter must be adopted as the higher principle of classification.

268. Acids.—The earliest definition of an acid was, that it is a substance of a sour taste, which turns vegetable blues red, and forms neutral salts with alkalies. Lavoisier added to the definition that it must contain oxygen as an element; and the class was gradually enlarged by the addition of bodies which have a bitter, and even a faintly sweet taste. Further research compelled chemists to admit into the class some bodies which contain no oxygen, others which do not affect vegetable blues, and others which are quite tasteless, until at last the only part of the original definition that is retained, is that they neutralize alkalies; a definition which is merged in the more comprehensive one now given, that they neutralize electro-positive compounds of the same genus, and are the electro-negative element of the compounds which they form.

269. Bases.—In the same manner, has the number of those bodies which acids are capable of neutralizing, been enlarged. Although chemists have been led to the inconvenient retention of the word acid, the common use of which is so different from its philosophical meaning; they have, by the adoption

of the term *base*, happily rid themselves of the like inconvenience in speaking of those bodies with which acids combine. The term *base*, is used to express all those electro positive compounds which are capable of combining with electro-negative ones, (generally of the same genus) and which, in so combining, acquire new generic properties. This extension of the meaning of the term *base*, has given a corresponding extension to the antagonist term *acid*.

270. *The Haloid Salts*.—The term salt, like the term acid, carried with it into philosophy its popular meaning, and here also it has been found necessary to extend its meaning, so as to admit substances which possess no sensible saline properties. Restricted, originally, as was believed, to the combination of an acid with an alkali, it has been found that the most eminently saline of the whole class, contain neither acid nor alkali, but are direct binary compounds of metals with certain electro negative elements.

This group of salts is called, by Berzelius, the Haloid Salts, and consists of the metallic compounds of the *Salt-Radicals*—Chlorine, Iodine, Bromine, and Fluorine.

271. The bi-elementary compounds will here be classed under the following heads; viz: Oxides, Chlorides, Iodides, Bromides, Fluorides, Sulphurets, Phosphurets, Carburets, and Alloys.

SECTION I.

THE OXIDES.

272. The oxides form several well defined groups. The non-metallic elements, are all placed at the negative end of the scale, and their oxides are, with

the exception of a few protoxides, the electro negative elements of a series of secondary compounds, and constitute the most numerous class of acids. The non metallic protoxides, which are not acids, do not appear to act the part of bases. If we regard hydrogen as a gaseous metal, which its chemical relations authorize us to do, there will be no exception to this rule.

Fluorine is the only element which has not yet been combined with oxygen.

273. Oxygen forms, with the metals at the positive extremity of the scale, a series of protoxides, having well marked characters. The protoxides of potassium, sodium, and lithium, are alkalies; those of barium, strontium, calcium, and magnesium, alkaline earths.

These protoxides are all powerful electro positive bases. The alkalies are distinguished by their great solubility in water, by a peculiar acrid taste, by turning vegetable blues green, and vegetable yellows brown, and by forming compounds soluble in water with oils. The alkaline earths have these properties in a less degree; baryta being the most, and magnesia the least alkaline of the series. A few of these metals form dentoxides and teroxides, which do not appear to possess either basic or acid properties.

The metals which rank next below these in the scale, are the bases of the earths, glucina, yttria, thorina, alumina, and zirconia; their oxides are characterized by tastelessness, insolubility, and difficult fusibility. But one oxide of each of these metals is known.

The highly basic properties of water, place it near the group of alkalies and alkaline earths, to the peroxides of which, the peroxide of hydrogen has also much analogy.

274. With most of the remaining metals, oxygen forms several oxides, of which the lower degrees of

oxidation are more or less basic, and the higher degrees are either indifferent to acids and to bases as the deutoxide of lead, or acid as the teroxides of chrome and manganese. The tendency to form acids with oxygen, is greatest in those metals which are nearest the electro negative end of the scale.

It will be most convenient to arrange the oxides into sub orders, corresponding with the above distinctions.

Sub-order First.

NON METALLIC OXIDES.

OXIDES OF CHLORINE.

275. *Protoxide of Chlorine, Hypochlorous Acid.*
 $\text{Cl O. } 35.42+8=43.42$. This acid is prepared by the agitation of finely powdered deutoxide of mercury with water in a bottle of chlorine gas. The gas is absorbed by the peroxide, a portion of which it decomposes. One portion of the chlorine unites with the mercury, and another with the oxygen that has been set free, forming hypochlorous acid, which is dissolved by the water. Pure hypochlorous acid is a gas of a pale yellow colour. Its concentrated solution has a strong acid, but not sour taste; and its odour is penetrating, somewhat resembling that of chlorine. It bleaches like chlorine, and destroys the epidermis like nitric acid. It is one of the most unstable compounds known. Its concentrated solution spontaneously decomposes, and the gas explodes with a flash of light when the temperature is slightly raised. Two volumes expand into three, of which one is oxygen, and two are chlorine. The hypochlorous acid combines with bases to form salts, which are remarkable for their bleaching properties.

276. *Peroxide of Chlorine. Chlorous Acid.*—
 $\text{Cl O}_2; 35.42+32=67.42$. This acid is prepared by carefully adding dilute sulphuric acid to chlorate of

potassa. The chloric acid, in being disengaged from the potassa, is itself decomposed, and every three atoms which are set free, form two of chlorous, and one of per chloric acid.

Chlorous acid is a gas, of a bright yellowish green colour, and an aromatic odour; it is rapidly absorbed by water, it has no action on mercury, it does not combine with the alkalies, and it destroys most vegetable colours. Phosphorus takes fire in this gas, causing an explosion; it explodes violently when heated to 212° , emitting a strong light. Forty measures occupy after explosion the space of 60 measures, of which 20 are chlorine and 40 oxygen, so that it is composed of 100 measures of chlorine and 200 of oxygen, condensed into 200 measures; its specific gravity is therefore 2.3374.

Chlorous acid gas is condensed by pressure into a yellow liquid. It forms salts with alkalies, which are speedily decomposed into chlorates and chlorides.

277. *Chloric Acid*.— Cl O_3 ; $35.42+40=75.42$. This acid may be obtained in solution, by the careful decomposition of a dilute solution of chlorate of baryta by sulphuric acid. It reddens vegetable blue colours, has a sour taste, and forms neutral salts called chlorates. It may be distinguished from chlorine by being destitute of bleaching properties, and from chlorohydric acid by not occasioning a precipitate in a solution of nitrate of silver. The solution of chloric acid may be concentrated by a gentle heat, until it acquires an oily consistence, when it has a yellowish tint, and the odour of nitric acid, and sets fire to paper and other dry organic matter. Chloric acid may be known by its property of forming with potassa a salt of a pearly lustre, which crystalizes in tables, and deflagrates on burning charcoal like nitre.

Chloric acid closely resembles nitric acid in its properties. It has never been obtained in an isolated form, being incapable of existing except in combination with water or a base.

278. Per Chloric Acid.— ClO_7 ; $35.42 + 56 = 91.42$. This acid is prepared from the perchlorate of potassa, by mixing it with half its weight of sulphuric acid, and heating the mixture; white vapours arise which condense in the receiver into a colourless liquid. Its concentrated solution has the specific gravity of 1.65, fumes lightly in the air, and boils at 300° . By distillation with sulphuric acid, in order to separate the superfluous water, a solid hydrate may be obtained in prismatic crystals. Like the chloric acid, it exists only in combination with water or other bases. It is the most stable of the oxides of Chlorine. It does not possess bleaching properties, and is one of the most powerful re-agents among the acids.

OXIDES OF IODINE.

279. Iodic Acid.— IO_3 ; $126.3 + 40 = 166.3$. This acid is formed when iodine is brought into contact with protoxide of chlorine. It is a white semi-transparent solid, with a strong astringent, sour taste, and no odour. Its density has not been ascertained, but it sinks rapidly in sulphuric acid. It fuses and is decomposed at 500°F . It detonates when mixed with inflammable organic substances, is deliquescent and very soluble in water, and forms salts which deflagrate like nitre.

280. Periodic Acid.— IO_7 ; $126.3 + 56 = 182.3$. This acid is analogous in its composition to per-chloric acid, though little is known of its properties.

OXIDES OF BROMINE.

281. Bromic Acid.— BrO_3 ; $78.4 + 40 = 118.4$. Bromic acid closely resembles chloric acid. Its solution cannot be concentrated beyond a certain point without undergoing decomposition. It is the only known oxide of bromine.

OXIDES OF SULPHUR.

282. Sulphurous Acid.— SO_2 ; $16.1 + 16 = 32.1$.
S acid is the sole product of the com-

bustion of sulphur in dry oxygen gas. The best method of obtaining it is by the action of sulphuric acid on mercury. When two parts of mercury and three of sulphuric acid are gently heated in a glass retort, the mercury is oxidated at the expense of a part of the sulphuric acid which is converted into sulphurous acid gas, that must be collected over mercury.

At the usual pressure and temperature sulphurous acid is a permanent gas, of the specific gravity of 2.2117, and of a suffocating, pungent odour; it extinguishes burning bodies without being itself inflammable, and is fatal to animal life.

Water dissolves 33 times its volume of this gas, and acquires its peculiar odour. The gas may be expelled unchanged by heat, but it is gradually converted into sulphuric acid by the absorption of oxygen from the water. Sulphurous acid bleaches most vegetable colours, without decomposing the colouring principle, for the colour may be restored by an alkali or stronger acid. It absorbs oxygen from water, nitric acid, and many other substances, and is converted into sulphuric acid; and it is, on the other hand, produced by the de-oxidation of sulphuric acid. It may be passed through red hot tubes without change, but is decomposed at a red heat by hydrogen, carbon, and potassium. Sulphurous acid liquefies under a pressure of two atmospheres. The liquid acid has a specific gravity of 1.45, and boils at 14° F.

283. *Sulphuric Acid*.— SO_3 ; $16.1 + 24 = 40.1$. Sulphuric acid is a tough, elastic, white crystalline solid; which liquefies at 66° F., and boils at 104° to 122°, forming, when there is no water present, a transparent vapour. This anhydrous acid has a powerful affinity for water; it emits dense white fumes in a moist air, and unites with an atom of water, forming the well known oil of vitriol, which is a liquid sul-

phuric acid, composed in its most concentrated state, of 1 sulphuric acid 40.1+1 water 9=49.1. When the vapour of this anhydrous acid is brought into contact with the dry alkaline earths, they combine with brilliant incandescence, and form the sulphates of these earths.

284. The sulphuric acid of commerce is prepared in two ways. The first is by decomposing the protosulphate of iron by heat. The salt is dried until it loses all its water of crystallization, and is then exposed in proper vessels to a red heat, which expels all its acid. This is the process pursued at Nordhausen in Germany, and the acid thus prepared is a dense, oily, brownish liquid, of the specific gravity of 1.9, which emits copious white fumes, and is known by the name of fuming sulphuric acid. By careful distillation, in a retort connected with a receiver surrounded by snow, a transparent vapour passes over and condenses into the tough crystalline mass already mentioned as anhydrous sulphuric acid. The liquid remaining in the retort is common oil of vitriol, so that the Nordhausen acid is a compound of the two, consisting, according to Dr. Thomson, of one atom of anhydrous, and one of hydrated acid.

285. The usual method of manufacturing oil of vitriol, is by the combustion of a mixture of eight parts of sulphur and one of nitrate of potassa. This is burnt in a furnace so contrived that the current of air which supports the combustion carries the products into a large leaden chamber, the bottom of which is covered to the depth of several inches with water. The nitric acid of the nitrate is decomposed, by the heat of the burning sulphur, into oxygen and deutoxide of nitrogen. The former supports the combustion, and the latter, uniting with the oxygen of the atmosphere, is converted into nitrous acid, and carried along with the sulphurous acid, into the

chamber. They here combine with the vapour of water into a crystalline compound, which is deposited on the walls of the chamber and in the water. By contact with water this crystalline compound is converted into sulphuric acid and deutoxide of nitrogen, the latter of which is reconverted into nitrous acid by the oxygen of the atmospheric air in the chamber, and combines with the sulphurous acid and vapour into the same crystalline compound, again to be decomposed into sulphuric acid and deutoxide. In this manner the whole of the sulphurous acid is converted into sulphuric. When the water in the chamber is sufficiently charged with acid it is drawn off and concentrated by boiling in leaden and glass vessels, until it has gained the density requisite for strong oil of vitriol.

286. Hydrated sulphuric acid, or oil of vitriol, is a dense, colourless, oily fluid, which boils at 620° F., has a specific gravity varying from 1.847 to 1.85. It is one of the strongest of the acids, separating all the others more or less completely from their combinations with the alkalis. It decomposes all vegetable and animal substances by the aid of heat. It has a strong acid taste, and reddens litmus paper even when very much diluted.

Sulphuric acid has a powerful affinity for water, extricating much heat during the combination, and forming several definite hydrates with it. When a dilute acid is evaporated at 400° , it acquires a specific gravity of 1.78, and becomes a hydrate containing two atoms of water, which solidifies at 32° , forming large regular crystals that remain solid at 45° . By evaporating a still more dilute acid at 212° in vacuo, a third hydrate is formed, having a specific gravity of 1.632, and containing three atoms of water. These hydrates appear to form distinct classes of salts.

287. When the vapour of sulphuric acid is passed

through a red hot porcelain tube, it is decomposed into two volumes of sulphurous acid, and one volume of oxygen.

288. There are two other acids of sulphur; the hyposulphurous S_2O_2 ; $32.2+16=48.2$, and the hyposulphuric S_2O_4 ; $32.2+40=72.2$. The former is a very unstable compound, and is remarkable for forming with silver a salt of an intensely sweet, without any metallic taste.

289. There is solid ground for believing that sulphurous acid is the only one of the above oxides that is a direct compound of sulphur and oxygen, and that it is the base of all the others. It is the only one which can be directly prepared from its elements, and it is always evolved in the decomposition of the others. On this view the sulphur in sulphurous acid is fully saturated with oxygen, and cannot unite with any more; but the acid itself acts as a compound radical, and combines with simple and compound bodies. It does not unite directly with oxygen, but it does so with nitrous acid, and the compound is decomposed by water, and produces sulphuric acid SO_3+O as detailed above. It combines with sulphur to form hyposulphurous acid SO_2+S , which is a true sulphur acid. Two atoms combine with oxygen to form hyposulphuric acid S_2O_4+O . It also combines with chlorine to form chloro sulphurous acid SO_2+Cl , with iodine to form iodo sulphurous acid SO_2+I , and with nitric oxide to form nitro sulphurous acid SO_2+NO_2 (Kane).

OXIDES OF SELENIUM.

290. *Oxide of Selenium*.— SeO ; $39.6+8=47.6$. Oxide of selenium is a colourless gas, which emits a peculiar and powerful odour, resembling decayed horseradish.

291. *Selenious Acid*.— SeO_2 ; $39.6+16=55.6$. Selenious acid may be obtained as a hydrate in pris-

matic crystals. It has the odour of chlorine, is very soluble, and is a powerful acid.

292. *Selenic Acid*.— SeO_3 ; $39.6+24=63.6$. The most concentrated form in which selenic acid has been obtained, is that of a liquid hydrate, containing an atom of water. Its specific gravity is 2.6, its boiling point 536° , and it is decomposed if further concentrated. It is a powerful acid, and when heated oxidizes gold, but not platinum. Its compounds with the bases so closely resemble the corresponding sulphates in colour, crystalline form, and external characters, that they are only to be known by being decomposed by chlorohydric acid, and detonating on ignited charcoal.

OXIDES OF PHOSPHORUS.

293. *Oxide of Phosphorus*.— P_3O ; $47.1+8=55.1$. Oxide of phosphorus is a solid of a red colour, insoluble, tasteless, and inodorous; permanent in the air at 662°F. , but taking fire at a low red heat.

294. *Phosphorous Acid*.— P_2O_3 ; $31.4+24=55.4$. This acid may be prepared by subliming phosphorus through bichloride of mercury in a glass tube. A limpid liquid is formed, which is a chloride of phosphorus, and which is converted into phosphorous and chlorohydric acids by the action of water. Phosphorous acid has a sour taste, and a smell somewhat resembling that of garlic. It has a powerful affinity for oxygen, and precipitates several of the metals from their salts in a metallic form. When anhydrous it takes fire upon being heated in the open air.

295. *Phosphoric Acid*.— P_2O_5 ; $31.4+40=71.4$. This acid may be prepared by oxidating phosphorus by means of nitric acid, and by decomposing the biphosphate of lime by means of ammonia.

Phosphoric acid is colourless; it reddens litmus paper and neutralizes alkalies; it is intensely sour to the taste, but does not destroy the texture of the

skin like sulphuric and nitric acids. When evaporated at 300° it becomes a dark thick liquid, like treacle, and consists of one atom of phosphoric acid and three atoms of water. This hydrate has been obtained in thin crystalline plates by careful evaporation *in vacuo*.

When this terhydrated phosphoric acid is heated to 415° it parts with one atom of water. When heated to a red heat it parts with two atoms, and hardens in cooling into a brittle, transparent solid, known by the name of glacial phosphoric acid, which is highly deliquescent, and can only be preserved in carefully closed glass or stone bottles. An anhydrous phosphoric acid is formed when phosphorus is burnt in dry oxygen gas.

The water, combined with phosphoric acid, appears to form with it three distinct chemical compounds, possessed of distinct and peculiar properties. The anhydrous and the glacial acid appear to be identical in their chemical relations, and form salts containing one atom of base and one of acid. They have been called metaphosphoric acid. The bi-hydrated phosphoric acid is distinguished by its property of forming di-salts, containing an atom of acid and two atoms of base. In those cases in which it unites with a single atom of base, an additional atom of water appears to be an essential element of the salt. This modification of the acid has received the name of pyrophosphoric acid. The ordinary phosphoric acid has a strong tendency to form salts containing three atoms of base, whether those atoms be altogether alkaline, or part alkali and part basic water. The salts formed by these modifications of phosphoric acid with the same base are likewise of modified characters, and have been regarded as striking instances of the law of isomerism.

There is another oxide of phosphorus, the hypophosphorous acid, which consists of two atoms of phosphorus, 31.4 , and one of oxygen, $8=39.4$.

OXIDES OF NITROGEN.

296. *Atmospheric Air*.—Although atmospheric air is not to be regarded as a chemical union of its elements, it belongs under this head.

The atmosphere is a mixture of 23 parts by weight, or 208 in volume, of oxygen, with 77 parts by weight, or 792 in volume, of nitrogen. They are not, therefore, combined in the ratio of an even multiple of their atomic numbers, which is the distinction between a mechanical mixture and a true combination. The atmosphere possesses all the characters of a mere mechanical mixture. There is no change in the form, bulk, or other qualities of its elements. All the bodies which have an affinity for oxygen attract it as easily from the air as if the nitrogen were not present. A mixture of the two gases in the same proportions has the same density and refractive power, and agrees in all respects with atmospheric air.

297. If a thin globe of the capacity of 100 cubic inches, provided with a proper stopcock, be weighed, and then carefully exhausted of its air by an air pump, it will be found that it has lost 31.0117 grains, when the thermometer stands at 60° F., (15½° C.,) and the barometer at 30 inches. One hundred cubic inches of water, at the same temperature and pressure, weigh 25245.8 grains. The atmosphere at the earth's surface is, therefore, 815 times lighter than water. It is also nearly 11065 times lighter than mercury.

298. The weight of the air is adopted as the standard with which the weight of all other aeriform fluids is compared. Its specific gravity is, therefore, assumed to be unity.

If a glass tube 32 or 33 inches long be filled with mercury, and then inverted in a vessel of mercury,

it will be found that a column of the fluid metal, 30 inches high, will be sustained in the tube by the pressure of the atmosphere on the surface of the mercury in the vessel.

The weight of a column of mercury one inch square, and 30 inches high, is nearly 15 pounds, which is, therefore, the pressure of the atmosphere at the earth's surface; but, as it presses equally in all directions, it is not felt by us. The weight of this column of mercury being a counterpoise to the weight of the atmospheric column, it follows that the height of an atmosphere of the same density throughout as at the surface would be 30 inches $\times 11065$, or $5\frac{1}{2}$ miles.

299. But as, in consequence of its elasticity, the density of the air decreases as we ascend, the actual height of the atmosphere is supposed to be about 45 miles. The elastic force which separates the particles becomes at last so feeble as to be no more than equal to the attraction of gravitation; and this equality limits the further separation of the particles, and determines the height of the atmosphere.

300. In virtue of the law of elastic fluids, that the density is directly as the pressure, a volume of air which, under a pressure of one pound, occupies 100 cubic inches, will be compressed into half the space by double the pressure, and expand into twice the volume under half the pressure; and it is a consequence of this law and of the law of gravity, that the density of the atmosphere decreases in a geometrical ratio when the height increases in an arithmetical one. It has been found by experiments made on the Puy de Dome—a mountain in Auvergne in France—that the barometer in ascending a height of 3000 feet falls from 28 to 24.7 inches. The twelfth term in a decreasing geometrical series, having the ratio 28 to 24.7, is 7.038, or nearly 7 inches. At the height of $3000 \times 12 = 36000$ feet, or

nearly 7 miles, the density of the air is therefore one fourth that of the surface, and the following table is founded on this calculation.

Altitude in miles.	Corresponding density.
0	1
7	$\frac{1}{4}$
14	$\frac{1}{16}$
21	$\frac{1}{64}$
28	$\frac{1}{256}$
35	$\frac{1}{1024}$
42	$\frac{1}{4096}$
49	$\frac{1}{16384}$

301. As the radiant heat of the sun passes through the air without any absorption, and does not therefore heat it, the atmosphere must receive its heat from contact with the earth.

The decreasing density of the atmosphere being a necessary consequence of its constitution as an elastic fluid; and also its capacity for heat being, as has been stated in the chapter on caloric, increased by rarefaction, and the earth being the source of that heat, it follows that the sensible heat of the atmosphere must decrease as the latent or specific heat increases; that is, in proportion to the height above the earth. For if we forcibly expand a stratum of air at any distance from the surface, it will rise until it reaches an equally rarefied stratum; its specific heat being increased, a sufficient portion of the sensible heat will be necessarily absorbed to supply it, and the temperature will fall. So, on the other hand, if a portion be forcibly condensed, it will sink until it gain its proper level; the specific heat being lessened, all the caloric thus disengaged will become free, and raise the temperature. It has accordingly been found that in ascending into the atmosphere the temperature falls one degree of Fahrenheit for about every 352 feet of height. There is conse-

quently in every latitude a point at which the thermometer never rises above 32° , or where ice does not melt. This point is called the point of perpetual congelation, and the line drawn through all these points, the line of perpetual congelation.

The following table shows the height of this point in different latitudes.

Lat.	Feet.	Lat.	Feet.
0	15.207	50	6.334
10	14.764	60	3.818
20	13.478	70	1.778
30	11.484	80	.457
40	9.001	85	.117

302. The atmosphere contains from 4 to 6-10,000ths of carbonic acid; a minute quantity of light carburetted hydrogen gas, and a variable quantity of aqueous vapour. The carbonic acid is greater in summer than in winter, and by night than by day.

303. The analysis of atmospheric air, is readily performed, in several ways. Phosphorus undergoes a slow combustion, at ordinary temperatures, and will abstract all the oxygen from a vessel of air in about thirty hours. Thin filings or shavings of lead rapidly combine with oxygen, and entirely remove it from the air. Oxygen combines with twice its volume of hydrogen to form water. When, therefore, a mixture of equal measures of atmospheric air and hydrogen, contained in a strong and graduated glass tube, is exploded by means of the electric spark, one third of the diminution in the volume is due to oxygen gas. The deutoxide of nitrogen also furnishes a ready means of analysis which will be noticed when treating of that substance.

304. The art of determining the purity of the air by these and other means, is called *Eudiometry*, and the instruments for ascertaining it *Eudiometers*, or measurers of pure air. After repeated experi-

ments in every variety of situation, it is fully ascertained that the proportions of the two gases do not sensibly vary on the top of the highest mountains, in the deepest forests, in the midst of the most crowded cities, over the ocean, and in the open verdant plains.

305. As respiration, combustion, and a great variety of other processes, are continually consuming the oxygen of the atmosphere, there must be some source of supply commensurate with these drains. This exists in the vegetable kingdom. Plants during the day absorb carbonic acid from the air, and evolve its oxygen; the carbon constituting their food. During night this process is reversed; but it has been ascertained that in the whole twenty-four hours they give out more oxygen than they absorb, and thus probably repair the continual waste from other causes.

306. *Protoxide of Nitrogen. Nitrous Oxide*, NO; $14.15 + 8 = 22.15$. This gas is prepared by heating the nitrate of ammonia in a retort to 400° or 500° F., at which temperature it fuses, and is rapidly decomposed. The following formula will explain the nature of the change which takes place.

Nitrate of ammonia consists of

1, nitric acid=1 nitrogen $14.15 + 5$ oxygen=40=54.15
1, ammonia=1 nitrogen $14.15 + 3$ hydrogen=3=17.15

71.30

When this salt is decomposed, the 3 atoms of hydrogen combine with 3 atoms of oxygen and form 3 atoms of water, while the remaining 2 atoms of oxygen combine with the 2 atoms of nitrogen and form 2 atoms of protoxide of nitrogen. It thus appears that 71.3 grains of nitrate of ammonia will yield 44.3 grains of the protoxide.

307. Protoxide of nitrogen is a colourless gas

which does not affect vegetable blues. Water dissolves its own bulk of it, acquires a sweet taste, and a faint, agreeable odour; but gives out the gas unchanged at 212° .

Many substances, when previously kindled, burn in this gas with great splendour. Iron wire, charcoal, phosphorus, and sulphur, when kindled, burn with as much splendour as in oxygen gas, and the glowing wick of a taper is immediately rekindled. It may be decomposed by a succession of electrical sparks, or by passing it through a red hot tube of porcelain. It is in both cases resolved into oxygen, nitrogen, and nitrous acid. When 100 measures of the protoxide and 100 of hydrogen are detonated together, both gases disappear, water is formed, and 100 measures of nitrogen gas remain. As the 100 measures of hydrogen combine with 50 measures of oxygen to form water, it is evident that 100 measures of protoxide consist of 100 nitrogen and 50 oxygen condensed into 100. Its specific gravity is thus easily determined to be 1.5239; for

100 cubic inches of nitrogen weigh	30.1650 grs.
50 do. oxygen	17.0936
<hr/>	
100 do. protoxide of nitrogen	47.2586

308. Protoxide of nitrogen will support respiration for a short time, not exceeding 3 or 4 minutes, and produces a temporary delirium, generally accompanied by the most agreeable feelings of excitement, which soon, however, subside. From four to nine quarts are breathed from a silk bag, and a few deep inspirations will be followed by feelings resembling those of the earlier stages of intoxication. These effects are not uniform, and they are occasionally of an unpleasant and alarming nature.

Under a pressure of 50 atmospheres the protoxide is condensed into a transparent liquid.

309. *Deutoxide of Nitrogen. Binoxide of Nitrogen. Nitric Oxide.*— NO_2 ; $14.15+16=30.15$. The best method of preparing this gas, is by the action of nitric acid of the specific gravity of 1.2 on copper turnings. The nitric acid parts with three atoms of its oxygen to the copper, and an atom of nitric oxide gas escapes. Three atoms of protoxide of copper are formed, which unite with three atoms of the remaining nitric acid to form the nitrate of copper.

310. The deutoxide is a colourless irrespirable gas, which excites strong and dangerous spasms in the glottis.

Very few inflammable substances burn in this gas; burning sulphur and a lighted taper are extinguished by it, but charcoal and phosphorus, if immersed when in vivid combustion, burn with increased brilliancy. With an equal bulk of hydrogen it forms a mixture which burns quietly with a greenish-white flame.

The deutoxide of nitrogen is partially decomposed by a succession of electrical sparks, and by passing through red-hot tubes. If potassium is heated in 100 measures of this gas, it is converted into potassa, the volume of the gas is reduced one half, and pure nitrogen is left in the vessel. The quantity of oxygen that combines with the potassium is 50 measures, so that the deutoxide is composed of equal volumes of nitrogen and oxygen, which unite without any change of bulk; its specific gravity is therefore 1.0375.

311. Deutoxide of nitrogen is distinguished from all other gases, by the formation of red vapours of nitrous acid, whenever it comes in contact with oxygen gas. This property renders it a very convenient test of the presence of oxygen, and useful in the analysis of atmospheric air. When 100 measures of this gas are introduced into a wide vessel containing 100 measures of atmospheric air, the red fumes are

speedily formed and absorbed by the water, and one fourth of the diminution which takes place is oxygen gas.

Both the protoxide and the deutoxide of nitrogen form compounds of considerable permanence with the pure alkalies.

312. *Hyponitrous Acid*.— NO_3 ; $14.15 + 24 = 38.15$. This acid may be formed by mixing 400 measures of deutoxide of nitrogen with 100 measure of oxygen, in a glass tube containing a strong solution of pure potassa and inverted over mercury. The acid which is generated unites with the potassa and forms a hyponitrite of potassa.

The hyponitrous acid is a liquid, colourless at 0°F . and green at common temperatures. In open vessels it rapidly passes off in orange vapours of the density of 1.72. When mixed with water it is decomposed into nitric acid and deutoxide of nitrogen.

313. *Nitrous Acid*.— NO_2 ; $14.15 + 32 = 46.15$. When deutoxide of nitrogen is mixed with oxygen, red fumes of nitrous acid are always formed. 200 measures of the deutoxide (100 nitrogen+100 oxygen) unite with 100 of oxygen and contract into 100 measures, so that the specific gravity of nitrous acid gas is 3.1775.

Nitrous acid vapour is condensed into a liquid at a low temperature, and the acid may be obtained in a liquid form by heating carefully dried nitrate of lead in an earthen retort to a red heat, and collecting the vapours of nitrous acid, which are formed, in a vessel surrounded by a freezing mixture. The liquid acid is highly pungent and corrosive; its colour at common temperatures is orange-red, at 32° is yellow, and at 0° it is colourless. Its density is 1.451, and its boiling point 82° . Nitrous acid gas is highly irrespirable and excites violent spasms of the glottis. It extinguishes burning sulphur, but phosphorus and a taper will burn in it with great brilliancy.

Nitrous acid readily parts with its oxygen to the more oxidizable bases, and is usually converted thereby into deutoxide. It is decomposed, and yields oxygen and nitrogen gases by being transmitted through a red-hot porcelain tube.

When nitrous acid gas is passed into water, it is decomposed into nitric acid and the deutoxide, the latter of which escapes with effervescence. The solution first becomes blue, then blueish-green, green, yellow, and orange, according to the relative quantity of nitric or nitrous acids. The more nitric acid the solution contains, the greater is the quantity of nitrous acid which it will retain without decomposition. When nitrous acid gas is heated, its colour gradually deepens, until it becomes at last absolutely black.

314. *Nitric Acid.*— NO_2 ; $14.15 + 40 = 54.15$. Nitric acid may be formed by passing a succession of electric sparks through a mixture of oxygen and nitrogen gases in which moisture is present. It may also be formed by slowly adding deutoxide of nitrogen to an excess of oxygen gas over water. It has been proved by this means that the acid consists of 100 volumes of nitrogen and 250 of oxygen.

Nitric acid cannot exist in an insulated state, and the most concentrated form in which it can be obtained is a combination of two atoms of acid and three of water.

The nitric acid of commerce is usually called aqua fortis, and is generally prepared by decomposing the nitrate of potassa by sulphuric acid. The presence of water is essential to the process, as without it a considerable portion of the nitric acid is decomposed; for it is driven off from the potassa by the superior affinity of the sulphuric acid, and not finding the quantity of water which is necessary to its separate existence, is resolved into nitrous acid and oxygen.

315. Nitric acid, in its purest and most concen-

trated form, is a colourless liquid—eminently acid in all its properties—of a specific gravity of 1.5 or 1.51, and containing 20 per cent of water. It emits dense, white, suffocating fumes, and absorbs water from the atmosphere. It boils at 248°F. , and may be distilled without material change. Dilute nitric acid may be concentrated by heat till it gains the density of 1.42; but if acid of a greater density than this be heated, it is weakened. The strongest nitric acid freezes at -50°F. , diluted with half its weight of water it congeals at $-1\frac{1}{2}^{\circ}\text{F.}$ while the addition of a little more water reduces the freezing point to -45°F.

Nitric acid has a great affinity for water, and heat is disengaged when the two are mixed; from this affinity for water it liquefies snow with great rapidity, so that a mixture of 4 parts of concentrated acid, and 7 parts of snow, reduces the thermometer from $+32^{\circ}$ to -30°F.

Nitric acid acts powerfully on all substances which have much affinity for oxygen. It oxidates nearly all the metals, and acts on tin, copper, and mercury, with great violence. It decomposes all vegetable and animal substances, and imparts to most of them, and particularly to the skin and nails, a permanent yellow stain. It acidifies sulphur and phosphorus, and when flung on burning charcoal greatly increases the brilliancy of the combustion.

OXIDES OF HYDROGEN.

316. *Water.* HO ; $1+8=9$.—Water is a transparent, colourless, inodorous, and tasteless substance, which is solid below 32° and fluid at ordinary temperatures. It refracts light powerfully, and conducts heat very slowly. In its fluid state it is an imperfect conductor, and in its solid state a non-conductor of electricity. A cubic inch of water at 62°F. and

30 in. B. weighs 252.458 grains, and its weight is taken as the standard to which the weight of all other bodies except gases is referred. Water is elastic and compressible, being compressed 51.3 millionths of its bulk by a pressure equal to that of the atmosphere. Water absorbs air by exposure to the atmosphere, and the only means of obtaining it absolutely pure is by distillation. Water, deprived of all its air by ebullition, absorbs gases to which it may be exposed in various quantities.

317. If the air separated from rain or snow water be examined, it will be found to contain from 32 to 34.8 per cent. of oxygen gas. Dalton and Henry found that 100 cubic inches of water, at the mean temperature and pressure, absorb, of

Sulphohydric acid gas,	100 cubic inches,	
Carbonic acid,	100	"
Olefiant gas,	12.5	"
Oxygen,	3.7	"
Carbonic oxide,	1.56	"
Nitrogen,	1.56	"
Hydrogen,	1.56	"

318. Water is one of the most useful and powerful agents we possess. It combines directly and in unlimited proportions with many bodies, mingling with fluids, and dissolving solids, which may be separated from it by heat with their original properties unchanged, and which retain, even in combination with it, their peculiar characters unaltered, except by dilution. It combines also in a definite ratio with many acids, bases, and salts. Thus the slaking of lime is occasioned by the union of that earth with an equivalent of water. The concentrated oil of vitriol of commerce, is a combination of an atom of sulphuric acid and an atom of water. Free nitric acid cannot exist except in combination with water, and the liquid acid is a compound of two atoms of acid with three of water. There are no less than three

distinct combinations of phosphoric acid and water, giving rise to distinct classes of salts characterized by the presence or absence of water as an essential element in their composition. These definite compounds of water have received the name of hydrates, a term liable to misconception from its use in connexion with other terms. The use in all these cases of the adjective *hydrated* would prevent any confusion with the names of other combinations of hydrogen.

The important relations of water to heat have already been pointed out in treating of caloric.

319. *Deutoxide of Hydrogen. Peroxide of Hydrogen.* H O_2 ; $1+16=17$.—Peroxide of hydrogen was discovered by Thenard in 1818. It may be obtained by carefully adding to water acidulated with chlorohydric acid, a sufficient quantity of the deutoxide of barium to neutralize it. One atom of the oxygen of the deutoxide unites with the hydrogen of the chlorohydric acid, and the other atom combines with the water, while the barium and the chlorine unite to form chloride of barium. By carefully adding sulphuric acid, the whole of the barium is precipitated in the form of sulphate of baryta, and free chlorohydric acid is left in the solution. The process is repeated by adding fresh portions of oxide and acid until the water will no longer take up oxygen, and the peroxide is then concentrated by evaporating *in vacuo* the water with which it is still diluted.

Peroxide of hydrogen is a colourless, transparent, inodorous liquid, of the specific gravity of 1.452. It has a peculiar metallic taste, and occasions a prickling sensation both on the tongue and skin: it whitens the latter, and at length destroys its texture; it bleaches litmus and turmeric paper; it remains liquid in the greatest cold to which it has been exposed, and is slowly volatilized *in vacuo*; at 59°F . it effervesces

from the escape of oxygen gas, and if heated to 212° F., detonates from the rapidity of its decomposition. Dilution with water and a few drops of strong acid, render it more permanent; but it is decomposed by most of the metals, and by many of the metallic oxides; during which the metals that have a strong affinity for oxygen are oxidated, while gold, silver, mercury, platinum, and its associated metals, retain the metallic state. The protoxides of many metals are converted by it into peroxides, and the peroxides of lead, mercury, gold, platinum, manganese, and cobalt, decompose the peroxide completely and instantaneously, without becoming more highly oxidated. So great is the heat evolved by the action of these peroxides, that the tube in which the experiment is conducted becomes red hot. All the metallic oxides which are reduced to a metallic state by exposure to a red heat, are also reduced when they decompose the peroxide.

OXIDES OF CARBON.

320. The constant presence of this element in the products of organic life, renders it convenient to defer the consideration of all its compounds, until we reach the department of organic chemistry.

OXIDES OF BORON.

321. *Boric Acid. Boracic Acid.* BO_3 ; $10.9 + 24 = 34.9$.—Boric acid is the only known oxide of boron. It is held in solution in the hot springs of Lipari, and of Tuscany. It also exists in combination with oxide of sodium, in the form of borax, a salt that is obtained from the waters of certain lakes in India.

Boric acid may be prepared by adding to a solution of borax in four times its weight of water, a

sufficient quantity of sulphuric acid to decompose the salt. The boric acid is deposited in white, brilliant, unctuous, crystalline, hexahedral scales, which may be purified by washing and crystallization.

Crystallized boric acid is composed of one atom of acid 34.9 and 3 atoms of water $27=61.9$. It is soluble in 25.7 times its weight of water at 60° , and in 3 times at 212° . When it is heated in a platinum vessel it fuses, the water of crystallization is entirely driven off, and the anhydrous acid remains, forming a hard, colourless, transparent glass, which bears a white heat without subliming.

The specific gravity of crystallized boric acid is 1.48; it is soluble in five parts of boiling alcohol, and the solution burns with a beautiful green flame. It is inodorous, and its taste is cool and bitterish rather than acid. It is one of the weakest of the acids, and though it reddens litmus paper feebly, and decomposes the alkaline carbonates, it turns turmeric paper brown, as do the alkalies, and unites as a *base* with the bi-tartrate of potassa. Borax melts readily, and promotes the fusion of the more refractory minerals, on which account it is much used in mineralogy and the arts as a flux.

OXIDES OF SILICON.

322. *Silicic Acid. Silica.*— Si O_2 ; $22.5+24=46.5$.—This acid, under its usual forms of silica, silicious sand, quartz, rock crystal, and flint, is one of the principal constituents of the rocky crust of the globe. It may be prepared by igniting rock crystals, plunging them while red-hot into water, and then pulverizing them.

Pure silicic acid, as thus prepared, is a light, white powder, rough and meagre to the touch, tasteless and inodorous, and fusible in the flame of the oxy-hydrogen blowpipe.

Solid silicic acid is insoluble in water, but the acid in its nascent state is soluble in considerable proportions, and the solution, when gently evaporated, deposits a bulky, gelatinous precipitate. This precipitate is a hydrated acid, and does not part with all its water, until heated to redness. Silicic acid crystallizes in hexahedral prisms, terminated by six-sided pyramids; the primitive form of which is an oblique rhomb. Its specific gravity is 2.66. Although silicic acid has no action on test paper, nor any of the sensible properties of an acid, it combines with alkalies and earths, and decomposes the alkaline carbonates; and possesses the properties of an acid in all its chemical relations.

Sub-order Second.

THE METALLIC OXIDES.

Group First.

ELECTRO NEGATIVE OXIDES—ACIDS.

323. The metallic acids are those of tellurium, (Te O_2 , Te O_3), arsenic, (As O_3 , As O_5), antimony, (Sb O_4 , Sb O_5), chrome, (Cr O_3), vanadium, (VO_3), osmium, (Os O_4), titanium, (Ti O_3), gold, (Au O_3), molybdenum, (MO_3), tungsten, (WO_3), columbium, (Ta O_3), tin, (Sn O_2), and manganese, (Mn O_3 , Mn_2O_7).

324. *Arsenious Acid.* — As O_3 , $75.4 \times 24 = 99.4$. Arsenious acid is always produced when arsenic is heated in the open air. It is usually met with as a white powder. It sublimes at 380° without previously melting, yielding *inodorous* vapours, which condense into a brittle colourless transparent mass, of a vitreous lustre and conchoidal fracture. This glass by exposure to the air gradually becomes opaque and milk white, a change which diminishes its specific gravity and increases its solubility. The transparent acid feebly reddens litmus paper, while the opaque

acid restores the blue to litmus paper previously reddened. Arsenious acid has a slightly sweet taste and leaves an acrid sensation on the palate. When slowly sublimed, it crystallizes in regular octohedrons: and it has also been obtained in hexagonal scales, the primitive form of which is the rhombic prism. One hundred parts of boiling water dissolve 9.68 parts of the transparent, and 11.47 of the opaque acid.

325. Arsenious acid is one of the most virulent of poisons, and its detection is an object of great interest to the chemist and physician. The most certain method is to reduce the acid to the metallic form. This is readily done by igniting a mixture of the suspected powder with black flux in a glass tube. The metallic arsenic sublimes as it is formed, and may readily be distinguished by the metallic film which forms in the tube.

Arsenious acid forms a perfectly insoluble salt with the protoxide of iron, which is therefore, when freshly prepared, and taken in sufficient quantity, an effectual antidote to its effects.

326. *Manganic Acid*.— MnO_3 . *Permanganic acid*, Mn_2O_7 . The former of these acids is so readily decomposed that it cannot be kept in a free state. The concentrated solution of the permanganic acid has a rich red colour, and is rapidly decomposed by contact with organic substances. It bleaches colouring matters, and at 86° , is resolved into oxygen, and peroxide of manganese.

These acids are prepared from a salt long known under the name of *chameleon mineral*. It is best prepared by finely triturating 7 parts of black oxide of manganese with 6 of chlorate of potassa, and adding a strong solution of 8 parts of caustic potassa. The mixture is to be dried, powdered, and kept at a red heat for one or two hours in a platinum crucible. The salt formed is the manganate of potassa, and

its solution which is of a rich grass green colour, soon becomes blue, purple, and red, from the deposition of oxide, and the formation of the permanganate of potassa.

327. *Chromic acid*.— Cr O_3 ; $28+24=52$. Chromic acid may be obtained in crimson needles of great brilliancy, by placing a slip of moistened paper in the vapour of perfluoride of chrome. Pure dry chromic acid is black when warm, and of a deep red, when cold; it is very soluble in water, has a sour taste and strong acid properties. It bleaches vegetable and animal colouring matters, parting with oxygen and being converted into the green oxide.

328. *Osmic acid* is formed when osmium is burned, and is obtained in long white needles, having a pungent acid odour. It is soluble in water, and has no action on vegetable colours.

The remaining acids present nothing of particular interest to the student. They are generally coloured, nearly or quite insoluble, and tasteless, and some of them are themselves basic to stronger acids.

Group Second.

329. This group comprehends the metallic oxides, which are neither acids, alkalies, nor earths.

They are generally coloured, and impart their colour by fusion to glass; a very few of them are slightly soluble in water; the protoxides are strong bases; while many of a higher degree of oxidation, show no tendency to combine with either acids or alkalies, and others appear to be capable of combining with both. As prepared in the laboratory, they are mostly in the form of opaque powders; though the greater number of them exist in nature in beautiful crystalline forms. When not tasteless, they have a peculiar metallic taste.

330. This group includes the oxides of antimony, Sb O_3 ; tungsten, WO_3 ; molybdenum, MoO , MoO_3 ;

gold, Au_2O_3 ; titanium, TiO_2 ; platinum, PtO , PtO_2 ; osmium, OsO , OsO_2 ; Uranium, UO , UO_2 ; rhodium, RO , R_2O_3 ; iridium, IrO , Ir_2O_3 ; IrO_2 , IrO_3 ; Vanadium, VO ; chrome, Cr_2O_3 ; mercury, HgO , HgO_2 ; palladium, Pd_2O , PdO , PdO_2 ; silver, AgO , Ag_2O ; copper, Cu_2O , CuO , CuO_2 ; lead, Pb_2O , PbO , PbO_2 ; tin, SnO , Sn_2O_3 ; bismuth, BiO , BiO_2 ; cobalt, CoO , Co_2O_3 ; nickel, NiO , Ni_2O_3 ; iron, FeO , Fe_2O_3 ; manganese, MnO , Mn_2O_3 , MnO_2 ; cadmium, CdO ; zinc, ZnO ; cerium, CeO , Ce_2O_3 .

331. The protoxide of mercury is a black insoluble powder, prepared by quickly mixing calomel (prochloride of mercury) with a solution of potassa.

The deutoxide of mercury is prepared, either by heating mercury in oxygen gas till it is oxidated, or by expelling the acid from nitrate of mercury by heat. It is the substance called red precipitate. It is commonly in the form of red crystalline scales, and is slightly soluble in water. The solution has a metallic taste, and turns delicate vegetable blues green.

332. The dinoxide of copper is the ruby copper ore of mineralogists; it is a reddish brown powder, much less acted on by moist air than pure copper, and which, therefore protects the surface of the copper, upon which it has been formed.

The protoxide of copper may be formed by igniting the nitrate of copper. It is a dull black powder, which is entirely reduced to metallic copper, when heated to a dull red heat in contact with carbon, or with hydrogen gas. As the quantity of carbonic acid, or of water, which is thus formed can be measured with great exactness, this oxide is preferred to all other reagents in the ultimate analysis of organic bodies.

333. *Lead* forms three oxides similar in composition to those of copper.

The dinoxide is a dark gray powder; the pro-

toxide is formed by exposing melted lead to the air until a crust of the protoxide collects on the surface; the protoxide is of a lemon yellow colour, and is the pigment called massicot; when partially fused by heat it is called litharge. It is insoluble in water, has a specific gravity of 9.4214, parts with its oxygen to combustible matters, has a foliated texture after being fused, and unites readily with earthy substances into a transparent glass.

The peroxide is of a dark brown colour, is insoluble in water, and converted by a red heat, and by strong acids, into protoxide and oxygen gas.

The mixture in variable proportions of the protoxide and peroxide of lead, forms the pigment known by the name of minium or red lead. Minium is formed by exposing lead to the continued action of a current of hot air, without allowing it to fuse. It has a bright scarlet colour, is much used as a pigment, and in the manufacture of flint glass.

The deutoxide of lead is remarkable for forming pyrophyri, with the organic acids. A mixture of $2\frac{1}{2}$ parts of perfectly dry tartaric acid, and of 8 parts of peroxide, or of 1 of oxalic acid, and $5\frac{1}{2}$ of peroxide, speedily inflames, and continues a long while at a red heat.

334. There are two distinct oxides of iron, the protoxide and the sesqui-oxide, or peroxide. The protoxide exists as a saline base in sulphate of iron, and is precipitated as a white hydrate, which is gradually converted by exposure to the air into the red oxide.

The peroxide or red oxide of iron is the mineral known by the name of *red hæmatite*; its hydrate, containing two atoms of water, is the mineral called *brown hæmatite*.

The peroxide is not magnetic; it tinges glass of a red or yellow colour. It is prepared by exposing the sulphate to an intense heat, and is known to arti-

sans by the name of *colcothar*, and *crocus martis*. The native black oxide of iron appears to be a compound of these oxides in various proportions.

335. The protoxide of zinc is formed during the combustion of zinc: it is a flocculent white powder, insoluble in water, fixed in the fire, and a strong salifiable base.

336. The protoxide of tin is prepared by decomposing the chloride, by an alkaline carbonate. The precipitate is the hydrated oxide, which must be carefully dried at a low temperature. It is a white powder which burns like tinder when suddenly heated to a red heat.

The sesqui-oxide of tin is soluble in chlorohydric acid, and the solution, on being mixed with a solution of chloride of gold, forms a precipitate much used in enamel painting, and called the *purple powder of Cassius*.

Group Third.

THE EARTHS.

337. The earths are tasteless, insoluble, white oxides, which are strongly basic; and they are the only known oxides of their respective metals. Yttria, and thorina, are protoxides, and alumina, glucina, and zirconia, sesqui-oxides. With the exception of alumina, they are very rare minerals. Thorina is the heaviest of all the earths, its specific gravity being 9.4. Glucina is remarkable for the sweet taste of its salts; and zirconia approaches, in many of its properties, to silica.

338. *Alumina*.— Al_2O_3 ; $27.4 + 24 = 51.4$. Alumina is one of the most abundant products in nature, constituting, in a greater or less state of purity, the different kinds of clay, and being a constituent of many rocks. Sapphire, and the ruby, two of the

most precious and beautiful of gems, are nearly pure alumina.

Alumina may be prepared by decomposing a solution of sulphate of alumina and potassa, by means of an alkali, and repeatedly washing the precipitate until all the sulphate of potassa is removed. The alumina forms a bulky gelatinous precipitate, which becomes a semi-transparent, and afterwards a white, friable mass, and can only be deprived of its water by exposure to a white heat. It may also be prepared by exposing the sulphate of alumina and ammonia to a strong heat, by which the acid and alkali are driven off.

Alumina is a tasteless, inodorous, insoluble, white, friable solid, which has a powerful affinity for water, attracting it from the air, and adhering tenaciously to the tongue. It forms with water a soft, cohesive mass, capable of assuming any form in the mould or the lathe, and retaining it when dry. Alumina is capable of uniting both with acids as a base, and with bases as an acid. It is separated from acids as a hydrate by all the alkaline carbonates, but the precipitate is redissolved by an excess of alkali.

Aluminium forms but one compound with oxygen, and we have therefore no direct means of ascertaining the atomic composition of alumina. It is from its close resemblance in its form, and in all its combinations, to the sesqui-oxide of iron, that chemists have inferred that it is a sesqui-oxide.

339. Alumina is remarkable for its tendency to unite with organic matters. If cotton cloth be immersed in a solution of acetate of alumina, the earth will deposit itself completely on the fibres of the cloth, and leave the acetic acid free. If the cloth be then dipped in a solution of some organic colouring matter, this also will unite with the alumina, and become fixed upon the cloth as a permanent dye.

Group Fourth.

THE ALKALINE EARTHS.

340. The metallic oxides of this group, are more or less soluble; they turn vegetables blues green, and with the exception of magnesia, they are alkaline to the taste; but they are inferior in all these qualities to the alkalies, and they do not form with oil compounds soluble in water, nor a transparent glass with silex.

341. *Protoxide of Barium, Baryta.*— BaO ; $68.7 + 8 = 76.7$. Baryta may be prepared by subjecting nitrate of baryta to a red heat, and by heating intensely a mixture of charcoal and the carbonate of baryta.

It is a gray powder, of the sp. gr. of 5. It has a sharp caustic alkaline taste, turns vegetable blues green, neutralizes the strongest acids, and requires a high temperature to fuse it. It is insoluble in alcohol, has a very strong affinity for water, in combining with which it extricates an intense degree of heat, and forms a bulky hydrate, consisting of one atom of baryta and three of water. This hydrate is soluble in three times its weight of boiling water, and crystallizes on cooling in transparent flattened prisms, which contain one atom of baryta and twenty of water.

342. Barium also forms a deutoxide, which may be prepared by heating four parts of baryta to redness, in a platinum crucible, and gradually adding one part of chlorate of potassa. The deutoxide is used in the preparation of the peroxide of hydrogen.

343. *Protoxide of Strontium, Strontia.*— Sr O ; $43.8 + 8 = 51.8$. Strontia so closely resembles baryta in its properties, that they were once supposed to be identical. It is prepared in the same manner from

its nitrate and carbonate. Its hydrate contains one atom of strontia and nine atoms of water, and is soluble in boiling water, which deposits on cooling, transparent crystals, in quadrangular tables, composed of one atom of strontia and twelve of water.

The salts of strontia tinge the flame of alcohol of a crimson colour.

344. *Protoxide of Calcium, Lime.*— Ca O ; $20.5 + 8 = 28.5$. Lime is a brittle, white, earthy solid, of the specific gravity of 2.3. It has a strong affinity for water, and combines with it into a solid hydrate, consisting of an atom of each. Much heat is extricated during this combination, and the process is called slaking. Hydrate of lime parts with its water at a red heat; it is soluble in water, and the solution has an acrid alkaline taste, and turns vegetable blues green. Lime is more soluble in cold than in hot water, being soluble in 635 parts of water at 32° , in 778 at 60° , and in 1270 at 212° . By careful evaporation of this solution *in vacuo*, and absorbing the vapour by means of sulphuric acid, lime has been obtained in transparent hexahedral crystals containing an atom of water. Lime is one of the most infusible bodies known, melting with difficulty in the flame of the oxy-hydrogen blowpipe. When heated to full redness it phosphoresces powerfully, a property possessed also by the other alkaline earths.

Lime is prepared by exposing its carbonate to a full red heat: it has a strong affinity for carbonic acid, with which it forms an insoluble salt, and must therefore be carefully kept from the air. The salts of lime give to the flame of the blowpipe a dull, brownish red colour.

345. *Protoxide of Magnesium, Magnesia.*— Mg O ; $12.7 + 8 = 20.7$. Magnesia is a white, friable powder, of an earthy appearance, and, when pure, tasteless and inodorous. Its specific gravity is 2.9, and it is highly infusible. It has a feebler affinity for

water than lime, and in its combination with that liquid does not extricate heat, but forms, and slowly consolidates beneath water into a solid cement like plaster of paris. Like lime, magnesia is more soluble in cold than in hot water, although it dissolves very sparingly in either. It is soluble in 5142 times its weight at 60°, and 36,000 times at 212°. The solution is too weak to affect vegetable blues, but pure magnesia turns litmus paper brown. The hydrate of magnesia is found native, and contains an atom of each of its elements. Magnesia has a strong affinity for carbonic acid, and must therefore be preserved in close vessels.

Group Fifth.

THE ALKALIES.

346. The word *kali* is the Arabic name of a plant, from the ashes of which the alkali, now called soda, was obtained. It has been incorporated into the languages of Europe, and has passed into a generic term, signifying substances of an acrid bitter taste, soluble in water, turning vegetable blues green, and the yellow of turmeric brown; forming soaps with oil, and salts with acids, and having a powerfully caustic action on the skin. Three alkalies have long been known in the arts, viz. potash, or potassa—the vegetable alkali which is obtained from the ashes of plants in general; soda, or natron—the mineral alkali, which is obtained from the ashes of marine plants, and is also found as a saline concretion from the waters of certain lakes; and ammonia, or the volatile alkali, which is evolved during the decomposition of animal substances. A fourth, named Lithia, has in modern times been added to the list. The description of ammonia will be deferred to the department of Organic Chemistry.

347. *Protoxide of Potassium, Potassa.*— KO , 39. $15+8=47.15$. Pure potassa can only be prepared by exposing thin laminæ of potassium to the action of dry oxygen gas. It is a white, solid, highly caustic substance, fusible at a temperature above redness, and neither volatilized nor decomposed in the strongest heat to which it has been exposed. It has a powerful affinity for water, with which it forms a solid hydrate. This hydrate, which was long regarded as the pure alkali, will bear the strongest heat without decomposition; it fuses at a heat below redness, and assumes a crystalline structure in cooling. It is soluble in alcohol and in half its weight of water, and is much employed in surgery as a caustic. The solution of potassa is highly caustic, and must be kept in carefully closed vessels, as it rapidly absorbs carbonic acid from the atmosphere.

Hydrate of potassa is prepared by decomposing the carbonate of potassa by means of lime. The lime forms an insoluble compound with the acid, and sets the alkali free. The solution is filtered and concentrated, rapidly by boiling in a leaden, and at the close of the operation, in a silver vessel.

348. *Protoxide of Sodium, Soda.*— NaO ; $23.3+8=31.3$. The protoxide of sodium, soda, or natron, is formed by the oxidation of sodium in dry oxygen gas. In its anhydrous state it is a gray solid, difficult of fusion, and closely resembling potassa. With water it forms a solid hydrate, which is very caustic, soluble in water and alcohol, and like potassa eminently alkaline. It is prepared from its carbonate in the same manner as potassa.

The salts of soda are all soluble in water, and tinge flame of a yellow colour.

349. *Protoxide of Lithium, Lithia.*— LO $10+8=18$. Lithia is closely allied to potassa and soda, but tinges flame of a red colour, has a greater neutralizing power, and forms sparingly soluble compounds with carbonic and phosphoric acids.

SECTION II.

THE SULPHURETS.

350. The compounds, of which sulphur is the electro-negative element, closely resemble the corresponding compounds of oxygen.

351. *Sulphohydric Acid—Hydrosulphuric Acid—Sulphuretted Hydrogen.*— HS ; $1 + 16.1 = 17.1$. This acid may be prepared by heating one equivalent of sesquisulphuret of antimony, in a retort, with three equivalents of chlorohydric acid. A sesquichloride of antimony and sulphohydric acid are formed, the latter of which escapes in the form of a gas. Sulphohydric acid is a colourless, transparent gas, which becomes a limpid liquid under a pressure of 17 atmospheres. It feebly reddens litmus paper, and has a characteristic odour like that of putrid eggs. It is highly deleterious to animal life, even when very much diluted with atmospheric air. It extinguishes the flame of burning bodies, but is itself inflammable, burning with a pale blue flame, and at the same time depositing sulphur, and producing water and sulphurous acid. The sp. gr. of this gas is 1.1782. Water absorbs its own bulk of this gas, becomes feebly acid, and acquires its peculiar taste and odour. It is readily decomposed by nearly all the metals and non-metallic elements. It may be distinguished from all other gases by its peculiar odour, and by forming a black sulphuret with silver.

Sulphur forms another compound with hydrogen, a viscid, yellow liquid, of little permanence, which is probably a bi-sulphuret of hydrogen.

352. *The Metallic Sulphurets.*—The metallic sulphurets are opaque, brittle solids, many of which possess a metallic lustre; they are all fusible and crystallizable; most of them are fixed in the fire, and a few are volatile; some of them are remark-

able for the beauty of their colours; the protosulphurets are difficult of decomposition; while those containing more than one atom of sulphur are readily decomposed. The sulphurets of arsenic, antimony, tungsten, molybdenum, tellurium, tin, and gold, are electro-negative compounds, and true sulphur acids. The combination of several of the metals with sulphur, is attended with the disengagement of intense light and heat, and when the heated metal is exposed to the vapour of sulphur, it exhibits all the phenomena of combustion.

353. The sulphurets of the alkaline metals, potassium and sodium, are deliquescent and soluble, and greedily attract oxygen from the atmosphere. The sulphuret of sodium is the colouring principle of the celebrated blue mineral pigment, lapis lazuli.

The tersulphuret of potassium is a solid of a liver-brown colour, and is known by the name of liver of sulphur.

354. Sulphuret of potassium, in a state of minute division, takes fire at the ordinary temperature. A preparation of this kind, called *Homborg's Pyrophorus*, is made by heating equal weights of perfectly dry and finely powdered sugar and alum, or 3 parts of lampblack, 4 of dried alum, and 8 of carbonate of potassa. The mixture is to be kept at a red heat, in a tube or bottle, until inflammable gas ceases to be evolved. It must be kept from contact with the air, in which it is spontaneously inflammable.

355. The sulphurets of barium, strontium, and calcium, are soluble in hot water, and form transparent crystals, containing water of crystallization. These sulphurets, when exposed to the solar ray, absorb light, which they emit so copiously in the dark as to become luminous, or phosphorescent. Canton's phosphorus is a sulphuret of calcium, which is thus luminous, and which is prepared by exposing flowers of

sulphur and calcined oyster shells for an hour to a red heat.

356. The *bisulphuret of iron*, or *iron pyrites*, is one of the most abundant ores of iron. It has a yellow colour, strikes fire with steel, and crystallizes in cubes, or some allied forms.

The *sulphuret of zinc* is found abundantly in nature, and is called *blende*. It is red, brown, yellow, or black, with a peculiar resinous lustre.

The *protosulphuret of arsenic* is of a ruby red colour; and the *sesquisulphuret*, of a rich lemon yellow. The former is known to mineralogists by the name of *realgar*, and the latter by that of *orpiment*. They are employed as pigments; undergo sublimation without change, and are electro-negative in their relations to most other sulphurets.

The *bisulphuret of molybdenum* is a solid of a steel-gray colour, closely resembling graphite. It is the ordinary ore of the metal.

The *sesquisulphuret of antimony* is the ordinary ore of antimony. It crystallizes in rhombic prisms and needles, is of a reddish gray colour and a metallic lustre. The $\frac{1}{2}$ *sulphuret*, or *persulphuret*, is a powder of a red colour, occasionally used in pharmacy.

357. The *disulphuret of copper* is the mineral called *copper glance*. The *sulphuret of copper*, combined with the *protosulphuret of iron*, forms the mineral called *copper pyrites*.

The *sulphuret of lead* is *galena*, the most abundant ore of that metal. It crystallizes in cubes, and the allied forms, is of a steel gray colour and metallic lustre.

The *bisulphuret of mercury* occurs native, and is called *cinnabar*. It is prepared artificially by fusing sulphur with six times its weight of mercury, and subliming in close vessels. When this sublimate is reduced to powder, it forms the beautiful pigment *vermillion*.

The *sulphuret of silver* is the mineral called *silver glance*.

SECTION III.

THE SELENIURETS.

358. *Selenhydric Acid. Hydroselenic Acid.*— H Se ; $1+39.6=40.6$. This acid exists in the form of a gas, which at first has the odour of sulphohydric acid and then paralyzes for a time the sense of smell. It is absorbed freely by water, and the solution reddens litmus paper, and gives a brown stain to the skin. It is soon decomposed by exposure to the air.

The metallic seleniurets closely resemble the corresponding sulphurets, and do not require a particular description.

SECTION IV.

THE PHOSPHURETS.

359. Phosphorus combines with several metals; and the union is effected by bringing them in contact at a high temperature. The phosphuret of calcium is prepared by passing the vapour of phosphorus over red hot lime. It is a solid of a reddish-brown colour, which when thrown into water, is decomposed, disengaging spontaneously inflammable phosphuretted hydrogen gas.

SECTION V.

THE HYDROGURETS.

360. *Sesquihydroguret of Phosphorus.*— P_2H_3 . This compound, which is commonly called phosphu-

retted hydrogen, is a colourless gas, with a disagreeable odour, resembling that of garlic. It takes fire spontaneously in chlorine gas, is sparingly soluble in water, and when mixed with atmospheric air or oxygen gas, it detonates by the electric spark, or by a sudden expansion, as when a tube containing the mixture over mercury is quickly lifted a few inches.

Phosphuretted hydrogen may be prepared by heating hydrated phosphorous acid in a retort. Phosphuretted hydrogen gas may also be obtained by heating phosphorus in a strong solution of pure potassa. The gas obtained by this process takes fire spontaneously on coming into contact with atmospheric air, each bubble, as it rises to the surface of the pneumatic bath, exploding with a bright flame, and forming a ring of dense white smoke, which rises slowly with a graceful waving motion. The spontaneous inflammability of the gas prepared in this way, is supposed to be owing to the presence of a minute quantity of a spontaneously inflammable oxide of phosphorus; for it is destroyed by the presence of the vapour of any of the carburets of hydrogen, by potassium, phosphorous acid, and other substances which have a strong affinity for oxygen. The phosphuretted hydrogen, also, which does not possess the property, may have it communicated by a slight impregnation of nitrous acid gas.

361. The sesquihydrouret of arsenic is a gas highly deleterious to animal life, and analogous to the phosphuretted hydrogen in many of its properties.

These gases form crystallizable compounds, analogous to the compounds of ammonia, with iodohydric and bromohydric acids, so that they appear to be feeble alkaline bases.

Hydrogen also forms a compound with tellurium which has acid properties.

SECTION VI.

THE ALLOYS.

362. The following are the most useful and well-known of these compounds. Arsenic renders the metals with which it is combined both brittle and fusible. One tenth part of arsenic gives to copper a white colour, like silver, and renders platinum fusible at a heat a little above redness. Two parts of tin alloyed with one of lead, fuse at 360° , and are called *fine solder*; *coarse solder* consists of four parts of lead and one of tin, and fuses at 500° . The best *pewter* consists of tin alloyed with small quantities of antimony, bismuth, and copper.

Eight parts of bismuth, five parts of lead, and, three parts of tin, form an alloy which fuses at 210° , and is called fusible metal.

Type metal is an alloy of four parts of lead, with one part of antimony.

363. Bronze is an alloy of ten parts of copper, with one of tin. Bell metal is composed of eighty parts of copper and twenty parts of tin. A small quantity of silver increases, while a small portion of lead and antimony greatly impairs the sonorousness of the compound. The speculum metal of telescopes consists of two parts of copper and one of tin. Brass is a compound of four parts of copper and one of zinc. Tombac, Dutch gold, and pinchbeck, are varieties of brass. The white copper or packfong of the Chinese, or, as it is called in Europe, German silver, is an alloy in variable proportions of copper, nickel, and zinc, with a small quantity, perhaps an accidental impurity, of either lead, cobalt, or iron.

364. The tinning of copper consists in covering that metal with a thin surface of tin, which is applied by heating a perfectly clean piece of copper to

the melting point of tin, and then rubbing it over with a piece of that metal.

Sheet iron is converted into an alloy of iron and tin by dipping it in melted tin; the latter metal penetrates the whole substance of the iron and forms an alloy, uniting some of the most valuable properties of its elements.

Steel forms alloys of remarkable hardness and toughness, with exceedingly minute quantities of silver, platinum, rhodium, iridium, and osmium.

The standard silver for coinage contains a thirteenth part of its weight of copper.

The combination of the other metals with gold greatly impairs its malleability and ductility. Copper gives it a red tint and great hardness. The standard gold coin contains a twelfth part of its weight of copper.

365. The combinations of mercury with other metals are called amalgams. An amalgam of seven parts of tin and three of mercury is used for silvering glass mirrors.

The amalgam for exciting electrical machines is composed of one part of tin, one part of zinc, and two parts of mercury.

An amalgam of gold and mercury is used for gilding brass.



SECTION VII.

BINARY COMPOUNDS OF THE SALT RADICALS.

366. Chlorine, iodine, bromine, and fluorine, constitute a natural group, possessing the closest affinities both singly, and in combination, and are all characterized by forming true salts with the electro-positive, or metallic bases. They have on this account been called salt radicals, and these binary salts

so closely resembling those of oxygen and sulphur, have been called by Berzelius, the *haloid* salts.

367. These elements, with the exception of fluorine, all combine as bases to form powerful oxygen acids. They unite with hydrogen to form compounds, eminently acid in their sensible properties, yet having remarkable analogies with the salts. Their compounds with each other, and with the other electro negative elements are in general either neutral, being destitute of either acid, basic or saline properties, or they belong to the same class of salt radicals as themselves.

The intimate relations which subsist between them will be best exhibited by arranging together their compounds with the same base.

368. *Chlorohydric Acid. Hydrochloric Acid. Muriatic Acid.* — HCl ; $1 + 35.42 = 36.42$. This acid may be prepared by decomposing chloride of sodium by oil of vitriol. The rationale of the process may be thus stated:—

Oil of Vitriol.		Chloride of Sodium.	
1 Sulphuric acid,	40.1	1 Chlorine,	35.42
1 Water, } 1 oxygen 8		1 Sodium,	23.3
} 1 hydrogen 1—9			
	<hr/> 49.1		<hr/> 58.72

Yield,

1 Sulphate of Soda.		1 Chlorohydric Acid.	
1 Sulphuric acid,	40.1	1 Chlorine,	35.42
1 Sodium,	23.3	1 Hydrogen,	1.
1 Oxygen,	8— 31.3		
	<hr/> 71.4		<hr/> 36.42

369. Chlorine and hydrogen gases combine slowly in the diffused light of day. But in the direct rays of the sun, they combine instantaneously with a violent explosion.

370. Chlorohydric acid is a colourless gas, of a pungent odour, and an acid taste. Under a pressure of 40 atmospheres, and at the temperature of 50° , it becomes fluid.

It extinguishes burning bodies; is quite irrespirable, although less irritating than chlorine.

Chlorohydric acid gas has a powerful affinity for water. Whenever it escapes into the air, a dense white cloud is formed by its combination with the vapour of the atmosphere. A piece of ice liquefies instantly on being immersed in this gas, and the gas rapidly disappears. A long wide jar of the gas being inverted, and opened under water, is filled as rapidly as if it had been a vacuum. Water absorbs 480 times its bulk of this gas, and acquires a density of 1.2109. The quantity of real acid contained in any solution, may be ascertained by the quantity of carbonate of lime it will neutralize.

When pure, the strong solution of chlorohydric acid is a dense colourless fluid, intensely sour, emitting copious white fumes, and even when very much diluted, reddening litmus paper. It combines with water in all proportions, and with the disengagement of heat. It is used in the arts by the name of muriatic acid, and is usually of a yellow colour, from containing iron.

371. Chlorohydric acid parts with its hydrogen to all substances that readily yield oxygen, and free chlorine is disengaged. This takes place when it is mixed with nitric acid, in the proportions of their atomic weights. The mixture has been called aqua regia, and nitro-muriatic acid, and is in fact a solution of chlorine, which combines with and dissolves gold, and platinum, and the other metals insoluble in the strongest acids.

Chlorohydric acid is composed of equal volumes of chlorine and hydrogen, which unite without condensation when mixed and inflamed. Its sp. gr. is therefore 1.2694. Its presence may always be detected by the dense white precipitate which it forms with the nitrate of silver.

372. *Iodohydric Acid. Hydriodic Acid.*— HI ; $1+126.3=127.3$. This acid is a colourless gas of the sp. gr. of 4.385, with a very sour taste, reddening vegetable blues, and having a powerful affinity for water. Its odour resembles that of chlorohydric acid, and it causes a white fog when it comes in contact with the vapour of the atmosphere. Water absorbs this gas copiously, and the saturated solution has a sp. gr. of 1.7. The solution is readily decomposed by oxygen, iodine being set free, and water being formed. Chlorine, nitrous acid, and various other substances that have an affinity for water and its elements, also decompose it.

373. *Bromohydric Acid. Hydrobromic Acid.*— H Br ; $1+78.4=79.4$. Bromohydric acid is a colourless gas with an acid taste and a pungent odour. It is irrespirable, and powerfully irritates the glottis. It is very soluble in water, and the concentrated solution is a dense liquid that yields white vapours by exposure to the air, and possesses strong acid properties.

374. *Fluohydric Acid. Hydrofluoric Acid.*— HF , $1+18.68=19.68$. When finely powdered fluor spar is mixed with twice its weight of sulphuric acid, and distilled with heat from a leaden retort into a leaden receiver surrounded with ice, liquid fluohydric acid is collected in the latter.

Fluohydric acid at 32° F . is a colourless fluid, which is dissipated at the ordinary temperature in dense white fumes. Its specific gravity is 1.0609, which may be raised to 1.25 by the addition of water. Its affinity for water is so great that the combination is accompanied with a hissing noise, as when red hot iron is quenched in water.

Its vapour is much more irritating and pungent than chlorine, and it is so destructive of animal matter that a drop of the liquid acid no larger than the head of a pin instantaneously disorganizes the skin and causes a malignant ulcer.

Fluohydric acid has a strong, sour taste, neutralizes alkalies, reddens litmus paper, and is a powerful acid. It acts energetically on glass, and on some of the metals.

375. The chlorides, bromides, and fluorides of sulphur and of phosphorus, are dense, acrid, volatile, fuming liquids; and their iodides, solids of a grayish black or orange colour, and all of them are readily decomposed.

376. The *chloride, and bromide, of Silicon*, Si Cl_3 , Si Br_3 , are dense, volatile, transparent liquids, which are resolved by water into silicic acid, Si O_2 , and chlorohydric and bromohydric acids, 3HCl , 3HBr .

377. The *Fluoride of Silicon*, Si F_4 , is a colourless, transparent gas, of the sp. gr. of 3.611, which extinguishes flame, irritates the lungs, and destroys animal life. It is instantly decomposed by contact with water—four atoms decomposing three atoms of water, forming one of silicic acid, Si O_2 , and one of *fluosilicic acid*, $\text{H}_2\text{Si}_2\text{F}_6$, or $2\text{Si F}_4 + 3\text{HF}$. Water absorbs 365 times its volume of this gas, and the resulting liquid has a strong, acid taste, and reddens litmus paper. In this process the silicic acid appears as a fine, semi-transparent film, which invests the mouth of the tube, and forms a continuous cylinder from it to the surface of the water.

The fluohydric acid unites with the remaining fluoride to form the acid above described. This acid combines with the metallic bases, forming a series of tri-basic fluo-silicates or of double fluorides, the formula for which is $\text{M}_3 + \text{Si}_2\text{F}_6$, or $2\text{SiF}_4 + 3\text{MF}$.
 378. Chlorine and fluorine unite with boron, BCl_3 , BF_3 , and form gases which are rapidly absorbed and decomposed by water. The former is resolved into boracic and *fluoboric acids*. The changes, and the resulting acids, closely resemble those described above.

The metallic chlorides, iodides, bromides, and fluorides, form the sub class of haloid salts, and will be considered in the following chapter.

CHAPTER IV.

OF SALTS.

SECTION I.

GENERAL VIEWS.

379. The preceding bi-elementary compounds differ greatly from each other in regard to their chemical energies. Some of them, as the peroxides of lead and manganese, are chemically indifferent, and do not unite either with acids or alkalies. On the other hand, the affinities of some of them are of great energy, and have a wide range. These affinities are, in great measure, restricted to the limits of their respective genera. Electro-negative oxides, for example, attract and combine with electro-positive oxides, and appear to be indifferent to the electro-positive chlorides, iodides, bromides, &c. The few anomalous cases which are exceptions to this, do not impair it as a general law. These secondary compounds belong to, and form by far the larger portion of the class of bodies called salts; and they are naturally divided into orders according to their proximate electro-negative element.

380. Nearly all the salts are solid at common temperatures. They are generally crystallizable and transparent. Their colour depends in general upon that of their elements.

The alkaline salts have a sharp, saline, or bitter taste, frequently producing a sensation of coldness in

the mouth. The metallic salts, such as those of copper, mercury, and silver, generally have a nauseous metallic taste. Salts are mostly soluble in water, although the rate of solubility differs greatly, and is variably affected by heat. Some do not dissolve in a smaller portion of boiling, than of temperate water; while others are soluble in a much smaller quantity of the former than of the latter. The most remarkable example of this is the sulphate of soda, the crystals of which are insoluble at 0°F. , and dissolve in less than one third their weight of water at 91.5° , while an increase of heat beyond this temperature lessens their solubility. The boiling point of a saturated solution of any salt is always higher than that of pure water, and increases with the affinity of the salt for that menstruum. Salts which have a strong affinity for water, attract moisture from the air and become liquid; such salts are said to be deliquescent. Others remain dry at the usual state of the atmosphere, but attract moisture in a damp air. Salts which dissolve more copiously in hot than in cold water, are deposited in regular crystals by the gradual cooling of the solution. Crystals are procured from those saturated solutions which are as strong when cold as when heated, by evaporating the water in a continued heat, or in a current of dry and warm air. The slower the cooling and evaporation, the larger and more perfect will be the crystals.

361. Many salts, during the act of crystallization, combine with and solidify a certain portion of water, which is called the water of crystallization. This quantity varies with different salts, but is uniform in those crystals of the same salt, which agree in form. Many salts which contain water of crystallization, part with it in a warm and dry atmosphere, and *effloresce* or crumble into a white powder.

Crystals which contain no water of crystallization,

or are anhydrous, upon being heated, frequently break into smaller fragments, which fly off with a sort of explosion. They are said to decrepitate, and the phenomenon is owing to their brittleness and unequal expansion by heat.

382. A saturated solution of any salt is still capable of dissolving another soluble salt, provided the two do not decompose each other. This law has been advantageously applied to the purification of crystals, by washing them with a saturated solution of the same salt, which removes all the soluble saline impurities they may contain.

383. It has become a question among chemists, what is the real constitution of a salt; and there is reason to believe that the old theory which supposed them to be constituted of an acid and a base, must yield to views which are the result of a wider and more profound generalization.

384. The perfect resemblance in their chemical relations, of those salts which are bi-elementary compounds of the first order, to those which are of a secondary order, is a strong presumption in favour of a similarity of constitution. Chloride of sodium, for example, is a true salt, in which the metal sodium is combined with a simple electro-negative element. We have many examples in organic chemistry of very complex compounds, acting the same part as the simple elements, passing from one combination to another, without undergoing decomposition, although incapable themselves of existing except in combination. Such compounds, on the common theory of salts, we must suppose the nitric, and chloric, and various other acids, to be; for they are incapable of existing except in combination with water, or some other base.

385. If then the chloride of sodium be the type of the order, a salt may be regarded as a binary compound of a metal with either a simple or a complex radical;

and the oxygen of an oxygen salt, instead of being distributed between the base of the acid and the metal, is wholly united to the former, so as to constitute the electro negative-element of the salt. Thus, for example, sulphate of soda will no longer be represented by the symbol $\text{Na O} + \text{SO}_3$, but by the symbol $\text{Na} + \text{So}_4$.

386. There are many facts which render this view highly probable. All the acids, in what may be called their active state, contain water, while the anhydrous acids exhibit a remarkable indifference to combination. Such is the fact with regard to sulphuric acid, the most energetic of the class. It does not redden litmus paper. It shows little disposition to unite with the dry alkalies or alkaline earths, unless they be strongly heated. On the other hand, when dry baryta is presented at common temperatures to oil of vitriol, they unite with such force as to become ignited. On this theory the hydrated acids belong essentially to the same class as the salts, and pass into salts by the substitution of an atom of metal for the atom of hydrogen. Oil of vitriol, for example, will be represented by $\text{H} + \text{SO}_4$, and the three acids of phosphorus by $\text{H} + \text{P}_2\text{O}_6$, $\text{H}_2 + \text{P}_2\text{O}_7$, and $\text{H}_3 + \text{P}_2\text{O}_8$, and their salts by $\text{M} + \text{SO}_4$, $\text{M} + \text{P}_2\text{O}_6$, $\text{M}_2 + \text{P}_2\text{O}_7$, and $\text{M}_3\text{P}_2\text{O}_8$.

387. The decisive proof of the correctness of this theory is to be found in the electrolytic decomposition of salts. The same current of electricity, it is well known, will decompose an equivalent of any binary compound. When a solution of sulphate of soda is placed in the voltaic circuit, both sulphuric acid and oxygen are found at one electrode, and soda and hydrogen at the other; from which it might be inferred that the electric force had been divided between the salt and the water, and that both had been decomposed by direct electrolytic action. If this were the case, the sum of the two decomposi-

tions should represent the decomposing energy of the current. But it is found that full equivalents both of the salt and the water have been decomposed, which is wholly inexplicable on the old theory. If the real constitution of sulphate of soda be $\text{Na} + \text{SO}_4$, this result can be clearly explained. The sodium, upon being disengaged, instantly decomposes an atom of water, and soda and hydrogen are evolved at the negative electrode. The negative element of the salt being incapable of a separate existence, seizes upon the hydrogen of an atom of water to form oil of vitriol $\text{H} + \text{SO}_4$, setting its oxygen free, and the two are evolved at the positive electrode.

388. The decomposition of the water is thus due to the secondary action of the current, and the quantity of the salt decomposed is in exact accordance with the electrolytic law.

389. In like manner, when a solution of sulphate of copper is decomposed by electrolytic action, metallic copper is evolved at the negative, and acid and water at the positive electrode, and the quantity of copper separated exactly represents the electric energy of the battery. These cases are precisely like those of the metallic chlorides, and they must be regarded as decisive proofs of the truth of the new theory.

390. These facts throw new light upon this department of chemistry, by the simplicity and beauty of the general laws which they establish. The great law of saline combination is, that in the same genus of salts, the number of equivalents of the electro-negative element in the base bears a constant ratio to the number in the acid. This ratio in the sulphates is as one to three, and the sulphates of the susquioxides are all ter-salts, and those of the deutoxides bi-salts: thus maintaining the same proportion of one to three between the oxygen of the base and the acid. This law is a necessary consequence

of the new theory; for a salt, and an acid in its active state, being both of them compounds of an electro-negative element, the one with a metal, and the other with hydrogen, the conversion of the latter into the former is effected by the simple replacement of the hydrogen by the metal. This takes place through the mutual decomposition of the acid and oxide, the hydrogen and oxygen of which form water; while their other elements unite to form the salt. A sesquioxide, therefore, requires three, and a deut-oxide two atoms of acid to neutralize it.

391. *Monobasic and Polybasic Acids.*—Some of those definite compounds which acids form with water, must be regarded as essential modifications of the acid. Thus the metaphosphoric acid, which contains an atom of water, is represented by $H+P_2O_6$; the pyro or bi-hydrated phosphoric acid is $H_2+P_2O_7$; and the common or ter-hydrated acid is $H_3+P_2O_8$. This view of their composition explains the nature of the combinations into which they enter. The metaphosphoric acid can form but one class of salts, namely, that containing one atom of metal, and it is therefore called a *monobasic acid*. The salts of the pyrophosphoric acid always contain two electro-positive or basic atoms, in which one or both atoms of hydrogen are replaced by a metal. The formula of its salts is $M_2+P_2O_7$ or $MH+P_2O_7$.

The ter-hydrated acid is a tribasic acid, for it forms salts which always contain three atoms of base, in which one, two, or all the atoms of hydrogen may be replaced by a metal. The formula of its salts will therefore be $M_3+P_2O_8$, $M_2H+P_2O_8$, or $MH_2+P_2O_8$, in all which formulæ M represents the metallic base.

It is not necessary that the same metal should replace all the hydrogen in these bi and tribasic salts. The tribasic phosphoric acid forms, for example, a phosphate of magnesia, alumina and water represented by $MgAlH+P_2O_8$.

This division of acids into monobasic and polybasic, is of great importance to the right understanding of the complicated details of this department of organic chemistry.

392. *Basic and Constitutional Water.*—The manner in which water enters into the constitution of acids and salts, greatly modifies the character and chemical relations of these compounds. The following examples will serve to unfold the laws which govern these combinations.

Sulphuric acid forms at least three definite compounds with water. The first is the common oil of vitriol, which must be regarded as HSO_4 ; the second is a hydrate, and the third a bi-hydrate of the first, and their formulæ are $\text{HSO}_4 + \text{Aq}$, and $\text{HSO}_4 + 2\text{Aq}$.

So, likewise, the definite combinations of nitric acid with water, must be regarded as HNO_3 , $\text{HNO}_3 + \text{Aq}$, and $\text{HNO}_3 + 2\text{Aq}$.

393. Most salts in the act of crystallizing, combine with and solidify a definite quantity of water, which is called water of crystallization.

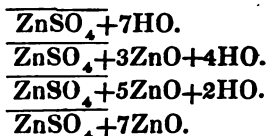
Thus, sulphate of zinc crystallizes with seven atoms of water. A portion of this exists in a different state of combination from the remainder, for when heated to 212° , the sulphate of zinc parts with six atoms, but retains the seventh until heated to 410° . This last atom is termed by Graham constitutional water, and it is always regained by the salt when moistened.

This atom of constitutional water may be replaced by an atom of a new salt, as in the present case, by sulphate of potassa. The sulphate of zinc unites with the sulphate of potassa to form the double sulphate of zinc and potassa, and this salt always crystallizes with six and not with seven atoms of water of crystallization, and it parts with them all at 212° .

The constitution of the two sulphates may be thus stated: $\text{HO} + \text{ZnSO}_4 + 6\text{Aq}$, and $\text{KSO}_4 + \text{ZnSO}_4 + 6\text{Aq}$;

so that the constitutional water of the first salt, represents the sulphate of potassa in the second.

394. As another neutral salt, of the same family, can take the place of the constitutional water in the above salt, so the oxide of the metallic base of the salt, may replace a part or the whole of its water of crystallization. Thus, for example, the following modifications of sulphate of zinc have been obtained.



395. So, likewise, the hydrated nitric acid, which is represented by $\text{HNO}_3 + 3\text{HO}$, may be regarded as a hydrated nitrate of hydrogen. When an atom of copper replaces the hydrogen, we have the common nitrate of copper, $\text{CuNO}_3 + 3\text{HO}$; and there is also a basic nitrate of copper, in which two atoms of water are replaced by two of protoxide of copper, $\text{CuNO}_3 + 2\text{CuO} + \text{HO}$.

396. This replacement of water by a metallic oxide, takes place also in the haloid salts. Thus we have an oxy-chloride of copper, $\text{CuCl} + 3\text{CuO}$ and an oxy-chloride of mercury, $\text{HgCl} + 3\text{HgO}$, which are exactly analogous to the combinations of the same chlorides with oxide of hydrogen, $\text{CuCl} + 8\text{HO}$, and $\text{HgCl} + 3\text{HO}$.

397. These views enable us to understand the true constitution of the bi-salts of the protoxides, of which an atom of water is always an essential element. Oil of vitriol may be regarded as a sulphate of hydrogen, HSO_4 and the bi-sulphate of copper as $\text{HSO}_4 + \text{CuSO}_4$. So, likewise, the bi-carbonate of potassa is in reality the double carbonate hydrogen and potassium, $\text{HCO}_3 + \text{KCO}_3$.

398. Salts of different acids with the same base,

may combine to form double salts, as the oxalate and nitrate of lead, and there are a few examples of double salts, containing two acids and two bases.

399. There are salts containing two or more atoms of acid and one of base, which differ essentially from the bi-salts above described, in containing the acid in an anhydrous form. Thus there is an anhydrous bi-chromate and ter-chromate of potassa, represented by $K CrO_4 + CrO_3$, and $K CrO_4 + 2CrO_3$. The chromic acid likewise combines with neutral haloid salts, for we have its anhydrous compound with chloride of sodium, and with chloride of potassium, the formulæ of which are $Na Cl + 2Cr O_3$, and by $K Cl + 2Cr O_3$. In these compounds the chromic acid seems to represent the water of crystallization of salts, which it replaces in the same manner as does the oxide of zinc.

400. These views of the constitution of salts, are confirmed by the nature of the organic compounds, which present many striking proofs of the same great law of substitution. It is probable that the establishment of this theory will render it necessary in the end, to remodel the language of chemistry. The present nomenclature is sufficiently expressive for ordinary purposes, and we possess in the invention of symbols, so accurate and concise a mode of representing the actual state of combination, that there is no pressing necessity for a change. The science is, moreover, at the present time, in a state of transition, which renders any attempt to reform its language premature.

401. *Isomorphism*.—It has been shown that all crystalline bodies belong to one of the six systems of crystallization already described, and that the same crystalline form must therefore be common to a great number of bodies.

When solutions of two salts, the crystals of which belong to the same system, and agree in the

length of their axes, are mingled and evaporated, the crystals which they form are found to consist of variable quantities of the two salts.

402. There is a very natural group of double sulphates, of which common alum is the type, and which consist of an atom of a tersesquisulphate combined with an atom of protosulphate. They agree in possessing a sweetish astringent taste, in reddening litmus paper, and in crystallizing in regular octohedrons. The base of the tersulphate in these alums may be the sesquioxide of alumina, of iron, of chrome, or manganese, and the base of the protosulphate, either potassa, soda or, ammonia. It would seem that when the elements of these various alums are present in solution, they may all contribute to the formation of a salt, which shall be a genuine alum, and yet consist of proportions altogether uncertain and accidental of the several species; the only condition essential to its formation being, that each atom consist of an atom of a protosulphate combined with an atom of a tersesquisulphate.

403. The application of this law to the science of mineralogy, bids fair to reduce its apparent confusion into order. There are many genera of minerals, of which hornblende or augite is an example, which are framed from the agreement of certain minerals in their forms of crystallization, and other mineralogical characters. The application of analysis to identify this agreement in external characters, threw the whole matter into a confusion which is only to be cleared up by this theory of the nature of the double isomorphous salts. Thus, augite was found to be a double salt, containing an atom of bisilicate of lime, combined with an atom of bisilicate of magnesia, which is the composition of that species of augite called *diopside*. In the species called *sahlite*, a portion, and in another species, the whole of the magnesia is replaced by protoxide of iron; in the

mineral called *hypersthene* the iron replaces the lime and not the magnesia; and the mineral called basaltic hornblende is a mixture of the bisilicates of lime, magnesia, iron, and *alumina*.

404. This property of isomorphism appears to depend upon similarity of atomic constitution. It is possessed, for example, by those oxides which contain the same number of atoms of oxygen and of base, and is carried throughout their similarly constituted compounds. Thus sulphuric, selenic, telluric, chromic, and manganic acids, contain three atoms of oxygen to one of base, and all their corresponding salts crystallize alike. Another well marked isomorphous group is the sesquioxides of iron, manganese, chrome, and aluminium. Phosphoric and arsenic acids constitute a third; and the protoxides of iron, manganese, copper, cobalt, nickel, zinc, magnesia, and lime, a fourth group.

405. Although that similarity of atomic constitution, of which the isomorphism of complex compounds is a result, must in the case of the elements and their simpler combinations, be accounted accidental; yet we find its value, as an indication of close affinity, to increase with the complexity of construction, and to obtain in organic chemistry a high value as an index of the properties of bodies.

SECTION II.

THE HALOID SALTS.

406. The binary compounds of the salt radicals with the alkaline, and earthy alkaline metals, are, with the exception of some of the fluorides, highly soluble crystalline sapid substances.

The chlorides and fluorides of some of the most

fixed metals are volatile fuming liquids or gases. The bromides and iodides are less volatile and liquid. Many of them are remarkable for the extreme brilliancy of their colour.

Their affinity for the metals is so great that their direct combination often presents all the phenomena of combustion. No heat that has yet been applied is capable of decomposing some of the chlorides. Sulphuric acid decomposes all these salts with the exception of the chlorides of silver and mercury.

THE CHLORIDES.

407. The *chloride of potassium* forms anhydrous cubic crystals, insoluble in alcohol, soluble in three parts of cold, and in still less of hot water, and having a saline, bitter taste.

The *chloride of sodium* is common sea and rock salt, and is one of the most abundant substances in nature.

It fuses at a red heat, is colourless and transparent, has a pure saline taste, is insoluble in pure alcohol, dissolves in $2\frac{1}{2}$ times its weight of both boiling and cold water, and crystallizes in anhydrous cubic crystals. It is a wholesome condiment, and from its powerful antiseptic properties is much used in preserving meat from putrefaction. It is much used in the arts for various purposes.

408. The *chloride of barium* is insoluble in alcohol, and dissolves in more than twice its weight of water. It crystallizes in flat four-sided tables, containing two atoms of water.

The *chloride of strontium* is soluble in alcohol and in water, and crystallizes in colourless prisms, containing nine atoms of water. Its alcoholic solution burns with a crimson flame.

The *chloride of calcium* is remarkable for its great solubility in and affinity for water. It may be ob-

tained in transparent prismatic crystals, containing six atoms of water, which are driven off at a red heat. It is much used for the preparation of freezing mixtures, and is very soluble in alcohol.

The *chloride of magnesium* is a transparent, colourless mass, soluble in alcohol and water, and, like the chloride of calcium, highly deliquescent.

The *sesquichloride of aluminium* has a highly crystalline lamellated structure, and a greenish-yellow colour, partially translucent, resembling talc; it is fusible and volatile at about 212° , and deliquescent in the air.

409. *Manganese* forms a *protochloride*, which is a pink-coloured, lamellated mass, and a $\frac{1}{2}$ *chloride*, or *perchloride*, which is a gas of a greenish copper colour, that condenses at about zero into a greenish-brown liquid.

Iron forms a *protochloride* which is a white crystalline solid, forming with water a greenish solution that yields crystals of the same colour. Its sesquichloride is volatile at 212° , and forms red iridescent crystals, soluble in water, alcohol, and ether.

The *chloride of zinc* is a colourless, transparent solid, that fuses at 212° , sublimes at a red heat, and deliquesces in the open air.

410. The *protochloride of tin* is a gray solid, of a resinous lustre, which fuses below redness, is soluble in water, and crystallizes in transparent prisms.

The *bichloride of tin* is a limpid fluid, which emits dense, white fumes in the open air, boils at 248° , and forms a solid hydrate. It is much used in dyeing, as a mordant for fixing and brightening certain colours.

The anhydrous *chloride of cobalt* is blue, and its hydrate is of a pink colour. Owing to this property its solution forms a sympathetic ink, which is colourless when cold and moist; while it is of a beautiful blue colour when heated.

Antimony forms a *sesquichloride*, a *bichloride*, and a *terchloride*. The *sesquichloride* is a soft deliquescent solid, liquefied by a gentle heat, and crystallizing in cooling. The *bichloride*, or $\frac{4}{3}$ chloride, is a compound of little permanence; and the *perchloride*, or $\frac{5}{3}$ chloride, is a transparent fuming volatile liquid. They are all decomposed by being dissolved in water.

The *chloride of lead* is a semi-transparent solid, fusible at a heat below redness, and having a sp. gr. of 5.13.

411. The *protochloride of mercury* is the well-known medicine, *calomel*. It is generally in the form of a white powder, which sublimes without fusion, at a heat below that of redness. The sublimate is a semi-transparent crystalline mass. Its sp. gr. is 7.2; it is insoluble in water, and is decomposed by solutions of the pure alkalies, the black protoxide of mercury being formed.

412. The *bichloride of mercury*, or as it is commonly termed *corrosive sublimate*, is generally prepared by subliming a mixture of one equivalent of the bisulphate of mercury, with two equivalents of chloride of sodium. The oxygen and the sulphuric acid combine with the sodium; one atom of bichloride of mercury is sublimed, and two atoms of sulphate of soda remain in the vessel. The *protochloride* is usually obtained from the bichloride, by triturating one equivalent of mercury with one of the bichloride, until all the metallic globules disappear, and then subliming the mixture. When mercury is heated in chlorine gas, it burns with a red flame, and is converted into bichloride.

Bichloride of mercury is a semi-transparent crystalline colourless solid, of a nauseously metallic, acrid, and burning taste. Its sp. gr. is 5.2; it fuses at a heat below that of redness, is soluble in twenty times its weight of cold, and twice its weight of boiling

water, and crystallizes in transparent prisms. It is also soluble in these proportions in alcohol and ether. It is one of the most virulent poisons known. The most delicate method of testing the presence of corrosive sublimate, is to place a drop of the suspected liquid on polished gold and touch the moistened surface with an iron or steel point, when the part touched instantly becomes white, owing to the formation of an amalgam of gold.

The bichloride forms with alkalies an orange-red precipitate, which is the deutoxide of mercury.

Many animal and vegetable substances have the property of converting the bichloride more or less rapidly into calomel. This change is almost instantaneously effected by albumen, and the solution of the white of eggs is consequently an antidote to the poisonous effects of corrosive sublimate.

413. *Chloride of silver*, as prepared by precipitation, is a white powder which gradually darkens in diffused day-light, becomes black in the direct rays of the sun, and is instantly blackened by the chemical ray at and beyond the violet extremity of the spectrum. It is insoluble in water, and most acids, but dissolves in a solution of ammonia. At 500° it fuses, and cools into a semi-transparent horny mass of the sp. gr. of 5.5.

The *protochloride of gold* is an insoluble yellow powder, which loses its chlorine, and is converted into metallic gold at a red heat.

The *terchloride of gold* may be obtained in fusible prismatic crystals, of a ruby-red colour. They are deliquescent and soluble in water, alcohol, and ether. The latter fluid withdraws the terchloride from its solution in water, and metallic gold is gradually deposited from this ethereal solution in crystalline flakes. At 400° it begins to part with its chlorine, and is converted, by increasing the heat, into the protochloride.

THE IODIDES.

414. Iodine has a powerful affinity for metals, although weaker than that of chlorine, oxygen, and bromine.

The iodides of the metallic bases of the alkalis and alkaline earths, like the corresponding chlorides, are eminently saline in their properties. They are white, semi-transparent, crystalline, soluble solids, saline to the taste, and decomposed by sulphuric and nitric acids. The iodides of the metallic bases of the earths are unknown.

415. Iodine forms with iron a protoiodide, which is a deliquescent, crystalline mass, of an iron-gray colour and metallic lustre.

The *sesquiodide* is a deliquescent, volatile red compound, soluble in water and alcohol.

The *iodide of lead* is obtained in crystalline scales of a brilliant yellow colour, forming a colourless solution in boiling water.

The *protoiodide of mercury* is an insoluble green powder; the *sesquiodide* is a yellow powder; and the *biniodide* is a powder of a rich scarlet colour, more beautiful though less permanent than vermilion. At 400° it fuses and sublimes. The vapour condenses in transparent yellow crystals, which assume a brilliant scarlet hue when cooled below 60° , or when rubbed or scratched with a sharp point.

THE BROMIDES.

416. Bromine has a powerful affinity for the metals, uniting with many of them with the extrication of intense light and heat. The properties of only a few of these compounds have been as yet examined. The bromides of potassium, sodium, barium, calcium, and magnesium are, like the cor-

responding chlorides and iodides, eminently saline in their qualities. They closely resemble the respective chlorides.

THE FLUORIDES.

417. The *fluoride of potassium* crystallizes in cubes, is sharply saline to the taste, deliquescent, and very soluble in water.

The *fluoride of sodium* forms anhydrous cubic crystals, and is sparingly soluble in water. Both these fluorides destroy glass by combining with the silica.

The *fluoride of calcium* is the well-known fluor, or Derbyshire spar, a mineral remarkable for its beauty and variety of colours, and the regularity of its crystalline forms. It crystallizes in cubes and octohedrons, is insoluble in water, fuses at a red heat, and is decomposed by sulphuric acid.

The *perfluoride of manganese* is a gas of a bright greenish yellow colour, that becomes of a beautiful purple red when mixed with the atmosphere; it is freely absorbed by water, and acts instantly on glass.



SECTION III.

THE OXYGEN SALTS.

418. *The Salts of Sulphur.*—These salts are the hyposulphites, represented by M, S_2O_3 ; the sulphites, M, SO_3 , the hyposulphates, M, S_2O_6 , and the sulphates M, SO_4 .

Of these salts, the sulphates are the only ones of importance.

419. The presence of a soluble sulphate may always be detected by chloride of barium, which occasions a white precipitate, insoluble in acids or

alkalies. An insoluble sulphate may be detected by exposing it, mixed with three times its weight of carbonate of soda, to a red heat. Double decomposition takes place, and a soluble sulphate of soda is formed, from which chloride of barium separates the acid.

Several of the sulphates, as those of baryta and lead, are altogether insoluble; those of lime and strontia are very sparingly soluble, and nearly all the others freely soluble in water.

All the sulphates, except those of the fixed alkalies and alkaline earths, are decomposed at a white heat; and when subjected to the combined action of carbon and heat, they are all converted into metallic sulphurets.

420. The sulphate of lime is found native in considerable quantities, and is known by the name of gypsum, or plaster of Paris. In its native state it usually contains two atoms of water, and fuses in its own water of crystallization; by exposure to a continued heat the water is driven off and the anhydrous sulphate remains in the form of a white powder. In this state it has a powerful affinity for water, eagerly combining with it into a compact solid mass. This property renders calcined gypsum very useful in taking casts and moulds. What is remarkable is, that by no process can we communicate this property of solidifying water, to gypsum which has once undergone the process.

The sulphate of baryta is also found abundantly in nature, and is called heavy spar.

421. The sulphate of soda, under the name of Glauber's salts, and that of magnesia, as Epsom salts, are much used as safe cathartic or purgative medicines.

The sulphate of the protoxide of iron is called copperas or green vitriol, and that of the protoxide of copper, blue vitriol.

The double sulphate of soda and lime is the mineral called *glauberite*.

The double sulphates that constitute alum have already been spoken of.

422. *The Salts of Nitrogen*.—These are the hyponitrites, M, NO_4 , the nitrites, M, NO_3 , and the nitrates, M, NO_5 .

423. The nitrates are all soluble in water, and it is for this reason difficult to detect their presence by any reagent. When chlorohydric acid is mixed with a nitrate, it is decomposed and chlorine is disengaged; the presence of which may be ascertained by its dissolving gold leaf. This test is not, however, a decisive one, where there is ground to suspect the presence of iodates, chlorates, seleniates, or bromates, as they exhibit the same appearance. The vegetable alkali, morphia, acquires an orange-red colour by the action of nitric acid, and may be used as a test of the presence of any of its combinations. The supposed nitrate is heated in a test tube with a drop of sulphuric acid, and then a crystal of morphia is added.

The only means of obtaining nitric acid, is by the decomposition of some one of its salts.

The nitrates of potassa, soda, lime, and magnesia, are found native, and their nitric acid appears to be formed, either during the decomposition of animal and vegetable bodies, or by the same kind of corpuscular action by means of which platinum promotes the combination of oxygen and hydrogen. They are found to be spontaneously generated in the soil in various parts of the world, and are artificially prepared by mixing calcareous earth with animal and vegetable remains. Nitric acid is generated during the decomposition of the organic matter, and combines with the earthy or alkaline bases which are present.

424. All the nitrates are decomposed by a high

temperature, and yield oxygen and nitrous acid, which cause the rapid combustion of any combustible or oxidable bodies that may be present. The phenomenon is called deflagration, and is generally performed by mixing equal quantities of the inflammable substance and the nitrate, and projecting them in small portions into a red-hot crucible.

The most useful of these salts, is nitrate of potassa, or nitre, as it is usually termed. It is a powerful antiseptic, and is much employed in preserving meat and animal matters from decomposition. It is used in the preparation of nitric acid, and in the manufacture of gunpowder, which is prepared by the intimate trituration and levigation together of 12.5 parts of sulphur, 12.5 of charcoal, and 75 of nitre. The theoretic constitution of the best gunpowder is S, C_3, KNO_6 , the decomposition of which produces sulphuret of potassium, and more than 1000 times its volume of nitrogen and carbonic acid gas.

425. The nitrate of silver is used as a caustic under the name of lunar caustic. It communicates a deep brown indelible stain to vegetable and animal substances, and is the basis of most of the indelible inks.

426. *The Salts of Chlorine.*—These are the hypochlorites, $M, Cl O_2$, the chlorites, $M, Cl O_3$, the chlorates, $M, Cl O_4$, and the perchlorates, $M, Cl O_5$.

427. The hypochlorite of lime is supposed to be the active element of the bleaching powder, which is sold under the name of chloride of lime. This powder, when properly prepared, consists of chlorine, oxygen, and lime, in their atomic proportions, and is probably a mixture of the hypochlorite of lime and the chloride of calcium, which may be represented by $Ca Cl O_2 + Ca Cl$.

428. The chlorates contain the same proportions of oxygen in the acid and base as the nitrates: viz. $MO + ClO_3$; and are very analagous to them. They are decomposed at a red heat, being resolved into a

metallic chloride, and yielding all their oxygen in the gaseous form. They deflagrate with inflammable substances more violently than the nitrates; a mixture of one part of sulphur, and three parts of chlorate of potassa, explodes when struck between two hard substances. A mixture of this, with a little charcoal or gunpowder, is sometimes used for the percussion caps for guns, but it is said to corrode the lock. A sulphur match, coated with a mixture of gum or sugar and chlorate of potassa, takes fire from the decomposition of the chlorate, when it is dipped in sulphuric acid, and is much used as a means of obtaining fire.

The chlorates are mostly very soluble salts.

The chlorate of potassa is obtained by passing chlorine gas through a mixture of two parts by weight of carbonate of potassa, and one part of hydrate of lime. By digesting the mass in water when saturated with chlorine, the solution is found to contain chloride of potassium and chlorate of potassa, which may be separated by crystallization. The reaction which takes place may be thus stated; $6K, CO_3$, and $6CaO, HO$, acted on by $6Cl$, produce $5KCl$; $6Ca, CO_3$, and $KClO_6$, while $6Aq$ are evolved.

429. *The Salts of Phosphorus.*—These salts are the hypophosphites, M, P_2O_2 , the phosphites, M, P_2O_3 , the monobasic phosphates, M, P_2O_6 ; the bibasic phosphates, M_2, P_2O_7 , $M+H, P_2O_7$; and the tri-basic phosphates, M_3, P_2O_8 , M_2+H, P_2O_8 , $M+H_2, P_2O_8$.

430. The several species of phosphates form one of the most remarkable and interesting groups of salts known to the chemist. The constitution of these salts has been most accurately studied in the case of the phosphates of soda, of which there are no fewer than six: namely, the monobasic phosphate, or metaphosphate, Na, P_2O_6 ; the two bibasic-

phosphates, or pyrophosphates, $\text{Na}_2\text{P}_2\text{O}_7$ and $\text{Na}+\text{H}, \text{P}_2\text{O}_7$; and the three bibasic, or common phosphates, $\text{Na}_3\text{P}_2\text{O}_8$, $\text{Na}_2+\text{H}, \text{P}_2\text{O}_8$ and $\text{Na}+\text{H}_2, \text{P}_2\text{O}_8$.

431. The common phosphate of soda of the shops, is the tribasic phosphate, with an atom of hydrogen, $\text{Na}_2+\text{H}, \text{P}_2\text{O}_8$. It is generally called the rhombic phosphate, and is manufactured in large quantities. It is alkaline to test paper, and crystallizes in oblique, rhombic prisms. When this salt is mixed with nitrate of silver, one equivalent of the yellow tribasic phosphate of silver is precipitated, and two of nitrate of soda, and one of free nitric acid, or rather of nitrate of hydrogen, remain in solution; the statement of this change being that $\text{Na}_2+\text{H}, \text{P}_2\text{O}_8$ and 3 Ag, NO_6 , yield $\text{Ag}_3, \text{P}_2\text{O}_8$, 2 Na, NO_6 , and H, NO_6 .

432. By the addition of pure soda to its solution, this salt is converted into the triphosphate, $\text{Na}_3, \text{P}_3\text{O}_{10}$, which crystallizes in slender prisms, having a strong alkaline taste. This salt throws down the yellow *triphosphate of silver* from the nitrate, three atoms of nitrate of soda being left in the solution, which is neutral.

433. When phosphoric acid is added to the rhombic phosphate, a new salt is obtained, of which the formula is $\text{Na}+\text{H}_2, \text{P}_2\text{O}_8$. It is very soluble, has an acid taste, and reddens litmus paper. With three equivalents of nitrate of silver, this salt yields one of the yellow triphosphate of silver, one of nitrate of soda, and two of nitrate of hydrogen, or nitric acid.

434. By heating the rhombic phosphate to a red heat, it is decomposed, an atom of water is evolved, and a new and less soluble salt is obtained, which is neutral to test paper, and which is the bi-basic phosphate or di-pyrophosphate; its formula being $\text{Na}_2, \text{P}_2\text{O}_7$. When an equivalent of this salt is mixed with two of nitrate of silver, a snow-white granular precipitate is formed, which is the bi-basic phosphate

or di-pyrophosphate of silver, and two atoms of nitrate of soda remain in the neutral solution.

435. When the tribasic phosphate, represented by $\text{Na} + \text{H}_3, \text{P}_2\text{O}_8$, is heated to 400° , it loses one atom of hydrogen, and when the heat is raised above 600° , it loses the elements of water, and is left as a simple pyrophosphate of soda, $\text{Na}, \text{P}_2\text{O}_7$. Its solution is neutral to test paper; it decomposes *two equivalents* of nitrate of silver, precipitating the snow-white granular di-pyrophosphate, and leaving one atom of nitrate of soda and one of free nitric acid, in the solution.

436. When this last salt is heated to low redness, it is converted into the monobasic phosphate or metaphosphate of soda, which is a very soluble, deliquescent, transparent glass, and reddens litmus paper. When mixed with an equivalent of nitrate of silver, gelatinous flakes which cohere into a soft mass by being heated, are precipitated. This is the monobasic phosphate or metaphosphate of silver.

437. It thus appears that these acids are distinct species, and carry their specific differences into their saline combinations. On the old theory of salts, the differences between the above phosphates is stated to consist in the greater or less number of atoms of *basic water*.

These acids form corresponding salts with the other bases; those of potash and lime have been examined. The triphosphate of lime is formed as a mineral in large mountain masses.

438. *The Salts of Arsenic*.—These salts are the arsenites $\text{M}, \text{As}_2\text{O}_3$, the monobasic arseniates, $\text{M}, \text{As}_2\text{O}_6$, and the bibasic and the tribasic arseniates, of which the constitution is the same as that of the corresponding phosphates.

The arseniates may be decomposed by being heated to redness with charcoal, which disengages metallic arsenic.

The arsenic acid resembles the phosphoric acid in its atomic constitution, and forms an isomorphous group of salts. The two groups are particularly interesting, as showing the influence which a similar atomic constitution exercises, not only over the form of crystallization, but over the chemical affinities and properties of bodies. Thus arsenic acid, like phosphoric, has a strong tendency to combine with three atoms of soda, forming a tri-arsenate, and this salt readily passes into one, with two atoms of soda and one of basic water, or into one with one atom of soda and two of basic water, corresponding in properties with the analogous phosphates. It also forms tri-arsenates, di-arsenates, and arseniates, with other of the metallic bases.

439. *The Salts of Chrome.*—The neutral chromates of the protoxides are isomorphous with the corresponding sulphates, their atomic constitution being the same, MO , CrO_3 .

The neutral chromate of potassa is of a yellow, and the bichromate of a ruby-red colour. The chromate of lead is an insoluble powder, of a brilliant yellow colour, and is much used as a pigment. The dichromate of lead is red, and the chromate of silver of a rich purple colour.

440. *The Salts of Boron.*—Owing to the feebleness of its chemical energies, boric acid is separated from all its compounds by most of the other acids, and yet, owing to its being fixed in a temperature in which most of the other acids are volatile, it will decompose even the sulphates at a red heat.

The biborate of soda is known in commerce by the name of borax, and is found native in certain parts of India; it is also prepared from the native boric acid of Tuscany. It turns vegetable blues green, and is used in the arts as a flux for promoting the fusion of the metals.

441. *The Salts of Silicon.*—The silicates are extensively distributed in the mineral kingdom, some

of them being the most abundant, and others the most beautiful of minerals. The double silicates especially, form a group of much interest to the mineralogist, from the light which they throw on the laws of isomorphism.

442. The silicates of potassa and soda are the bases of the different varieties of glass. Silicic acid combines with the alkalis in various proportions, and when a great excess of alkali is present, the compound is soluble in water. A mixture of 70 parts of carbonate of potassa, 54 of dry carbonate of soda, and 152 of fine quartz sand, forms a very soluble and fusible glass.

443. The different kinds of glass can scarcely be regarded as definite chemical compounds, so much as intimate mechanical mixtures of various silicates. When glass is kept in a soft state for a considerable time, the silicates gradually separate, the mass becomes opaque, almost infusible, and so hard, as to strike fire with steel. In this state it is called Reaumur's Porcelain.

444. The hard white glass made in Bohemia, which is so valuable to the chemist, consists of 70 per cent. of silica, 15 to 18.3 of potassa and soda, and 10 of lime; the English plate or crown glass contains 63 of silica, 22 of potassa, and 15 of lime; the green bottle glass of the French contains from 53 to 60 of silica, 3 to 5 of potassa, 21 to 30 of lime, and 15 to 12 of alumina and iron. English plate glass contains 52 to 60 of silica, 14 to 9 of potassa, and 33 to 28 of oxide of lead. The celebrated optical glass of Guinaud yields 42.5 of silica, 11.7 of potassa, and 43.5 of oxide of lead. The oxide of lead greatly increases the refractive power, brilliancy, and fusibility of the glass. In order to deprive glass of the extreme brittleness which characterizes it when suddenly cooled, it is kept for many days in an oven, the heat of which is very gradually lessened. The process is called annealing.

445. The various kinds of porcelain and earthenware are the silicates of alumina. The basis of them all is pure clay, which is a neutral silicate of alumina. In order to increase its fusibility, silica, lime, and potassa, are added, without which the clay would have so little coherence, and would contract so much in baking, as to destroy its value and beauty. The iron-stone china is formed of 40 parts of pure clay, 40 of feldspar, 5 of flint glass, and 10 of fine sand.

The various kinds of glass and porcelain are coloured by means of the metallic oxides, which fuse into highly coloured, transparent glasses with silica. Glass and porcelain are coloured blue by cobalt, green by chrome, copper, and iron; yellow by iron and silver; orange by nickel and silver; red by copper, crimson by gold, and purple by manganese.

SECTION IV.

THE SULPHUR SALTS.

446. These salts are the double sulphurets, as the oxygen salts are the double oxides. The resemblance of the two classes is perfect. The principal sulphur bases are the protosulphurets of the bases of the alkalies, alkaline earths, and earths; and the principal sulphur acids, the sulphurets of the bases of metallic oxygen acids, and in all these combinations, if the sulphur be replaced by oxygen, the corresponding oxygen acids, bases, and salts will be formed.

The most important of these salts are the sulphohydrates of potassium and sodium. They are crystalline soluble salts, of an acrid bitter taste, and are represented by the formula KS , HS , and NaS , HS . They form a delicate test of the presence of metallic salts, especially of those of lead, by the copious dark precipitate which they occasion.

PART SECOND.

ORGANIC CHEMISTRY; OR, THE CHEMISTRY OF THE COMPOUND RADICALS.

CHAPTER I.

GENERAL VIEWS.

447. It is impossible to frame a perfect system of arrangement for the facts of a science which is imperfectly understood, or has been but partially explored. The progress of knowledge consists, in truth, in the gradual development of the arrangement of physical phenomena, according to their essential relations; and those imperfect attempts at effecting this one great end of philosophical research, which subsequent discoveries have compelled us to reject as inadequate, are not without their use; and may serve as temporary lights to guide our footsteps along an uncertain path, until we gain the solid ground and clear daylight of truth.

In no science is the force of these remarks more to be felt than in organic chemistry. The vast variety and complexity of substances of which it treats, have hitherto obliged its cultivators to submit to an arbitrary classification, from which we are not at present able to disengage the science.

448. Among the various arrangements that have been proposed for this part of our subject, perhaps there is none more convenient than to class together the compounds of carbon.

There is this peculiarity in this element, that although it is itself the most tasteless, inodorous, insoluble and infusible of all substances, its compounds are generally liquid or gaseous, or very easily fusible solids, odorous, and readily undergoing decomposition. With hydrogen and oxygen it forms the basis of all vegetable, and with hydrogen, oxygen, and nitrogen, that of all animal structures, producing, by the combinations and permutations of these few elements, the innumerable complex forms of organic products.

449. The compound substances examined in the preceding part of this treatise, are characterized by the variety of the elements of which they are composed, and the simplicity of their laws of combination. In organic chemistry, on the other hand, we find substances of peculiar and even opposite properties composed of the same three elements, slightly differing in their proportions, and apparently baffling all attempts at a just classification.

Even here, however, we may perceive the dawn of a clear light, which will probably enable us to bring these multitudinous compounds under the same general laws that govern inorganic matter. A considerable number of them have already been ascertained to be binary compounds, of radicals more or less complex, which unite in the same manner as the simple elements with other bodies, and are capable of separation from their combinations, without themselves undergoing decomposition. We find in this department of chemistry, as in the other, acids, alkalies, and salts; and we also find a large class of compounds, the ethers and the essential oils, &c., of which inorganic chemistry furnishes few if any examples.

450. From a review of the various compounds which have passed under notice, it is evident that there are two great classes into which they may be divided; those namely, which are neutral or indif-

ferent in their chemical relations, as the salts; and those which possess energetic affinities, as the acids and alkalies.

451. Viewed from another point, they admit of being divided into two great classes; namely, one of binary compounds, formed by the union, atom to atom, of two elements; and the other consisting of several atoms combined into a single group, which acts the part of an elementary body.

452. Sulphurous acid, SO_2 , is a compound of the latter class; being the sole product of the direct union of sulphur and oxygen. The other oxides of sulphur are, as has been stated, conceived to be compounds of sulphurous acid, and not of sulphur itself. Thus hyposulphurous acid is $\text{SO}_2 + \text{S}$, and is a true sulphur acid, which unites with sulphur bases to form sulphur salts. Hyposulphuric acid is $2\text{SO}_2 + \text{O}$; sulphuric acid is $\text{SO}_2 + \text{O}$; chlorosulphurous acid is $\text{SO}_2 + \text{Cl}$; iodosulphurous acid $\text{SO}_2 + \text{I}$; and nitrosulphurous acid $\text{SO}_2 + \text{NO}$. By this mode of conceiving the nature of these bodies, we reconcile many seeming anomalies, and explain many phenomena not intelligible on the old view.

453. *Organic Radicals*.—There are numerous cases in which we are compelled to resort to similar suppositions respecting the constitution of compound bodies, in order to arrive at clear notions of the changes which they undergo, by the operation of chemical forces. There are, for example, several organic products which combine, amidst various changes of composition, with one or more atoms of most of the simple elements. When these various compounds are analyzed, the chemist perceives that there is a certain combination of atoms common to them all; and that if there were a substance so constituted, all the changes he has observed could readily be explained as so many combinations of that complex radical. Even if this substance cannot be sepa-

rated from its combinations and exhibited *per se*, the chemist has no hesitation in admitting its existence, and allowing it a place and a name in the list of organic elements.

454. Such an hypothetical radical is *benzule*. The essential oil of bitter almonds has long been a subject of interest and research to the chemist, on account of the powerful poison which it contains. Another organic product which has been subjected to frequent and accurate analysis, is the volatile acid obtained from gum benzoin. These substances have been subjected to the action of powerful reagents, and made to enter into combination with the simple elements. The result has been the full proof of the existence of the complex radical benzule, represented by $C_{14}H_6O_2$, although it has never yet been insulated. The protoxide of this substance is benzoic acid: with an atom of hydrogen it forms the oil of bitter almonds; and it enters into combination with chlorine, bromine, iodine, and sulphur, besides forming a great variety of other compounds with organic bodies.

455. It is evident that in these cases, the atoms which constitute benzule are held together by a stronger affinity than unites that radical to its several compounds, for it remains unchanged amidst a series of decompositions and recompositions.

456. The discovery of numerous radicals of this kind has entirely changed the state of this department of chemistry, and thrown a clear and steady light upon some of its obscurest portions.

These compound radicals belong to all the various classes which have been found to exist among the simple elements in inorganic chemistry. Cyanogen, NC_2 , is a genuine salt radical, belonging to the same class as chlorine and bromine; ethule, H_2C_4 , may be regarded as a compound metal, for it forms a series of basic oxides, which neutralize acids, and benzule

belongs to the group which contains the electro-negative elements, among which are the bases of the principal acids.

457. *Dependence of Chemical Properties upon similarity of Atomic Constitution.*—The searching analysis to which these bodies have been subjected, has proved new and most remarkable laws to govern their composition. The radical ethule, for example, passes unchanged into combination with a vast variety of substances, without having yet been insulated. At a red heat, oxygen will entirely decompose it, as it does all other organic products, converting it into water and carbonic acid. So, likewise, by the action of heat alone, almost all organic products can be separated into new or simpler combinations of their elements. These organic radicals are also capable of a partial decomposition which has peculiar laws. They may be regarded as groups of atoms, having a certain physical or mechanical structure, which appears to exercise some influence upon their affinities, and to resist decomposition, or to modify the action of reagents.

458. Thus, there is a radical called acetule, C_4H_3 , which forms a series of compounds with the simple elements; its hydrated oxide, $C_4H_3, O + Aq$, is the liquid called aldehyde, and its hydrated teroxide $C_4H_3, O_3 + Aq$, is acetic acid. Under certain circumstances, the radical itself is decomposed by chlorine, with the complete substitution of chlorine for hydrogen, so that a new radical, C_4Cl_3 , is obtained, which forms a series of combinations, parallel with those of acetule, and possessed of very analogous properties. Thus its terhydrated oxide is the chloracetic acid, $C_4Cl_3, O_3 + Aq$, which forms a series of salts parallel with the acetates, and preserving throughout, the analogy of characters which has been mentioned.

459. So likewise a series of organic compounds has been discovered, of which alcohol may be re-

garded as the type. They all agree in their general chemical characters; they all contain carbon, and hydrogen in their atomic proportions, and combined with two atoms of water; the abstraction of an atom of water, converts them all into substances having the generic qualities of ether, and by the substitution of two atoms of oxygen for the Hydrogen of their water, they are all converted into acids.

	Alcohol.	Ether.	Acid.
Wine alcohol,	$C_4H_4+2Aq,$	$C_4H_4+Aq,$	$C_4H_4+O_4.$
Wood alcohol,	$C_2H_2+2Aq,$	$C_2H_2+Aq,$	$C_2H_2+O_4.$
Oil of potato spirits,	$C_{10}H_{10}+2Aq,$	$C_{10}H_{10}+Aq,$	$C_{10}H_{10}+O_4.$
Ethal,	$C_{32}H_{32}+2Aq,$	$C_{32}H_{32}+Aq,$	$C_{32}H_{32}+O_4.$

460. Upon a closer examination it will be found that these changes and substitutions are in perfect harmony with the laws of inorganic chemistry. Decomposition destroys nothing, it merely changes. An element leaves the combination in which it exists, for a new one, because it is solicited by a more powerful affinity; and if in any case it is disengaged in its elementary form, it is because the associated atoms have been drawn away by a stronger attraction than its own, or because its own repulsion of elasticity, or attraction of cohesion, is stronger than its affinity for any of the elements, or combinations, that are present.

When a bi-elementary compound is decomposed, one of the elements is almost always set free, and in proportion to its complexity of constitution, do the elements of a body, instead of being separately evolved, reunite into new combinations.

We can readily understand why it is, that water and carbonic acid are the most constant products of vegetable; and water, carbonic acid, and ammonia, of

animal decompositions; for they are the most stable compounds, which the respective elements are capable of forming with each other, and they are always produced when the elementary affinities have full play.

461. *Law of Substitution.*—The partial decomposition moreover, which these complex organic products frequently undergo, and which changes the character, but not the number, nor probably the arrangement of the atoms, by substituting an equivalent of another kind for the one which is removed, is an exemplification of the same law.

462. When acetule is subjected to the action of chlorine, six atoms of chlorine are engaged in the decomposition of a single atom of acetule. Three of these unite with the three atoms of hydrogen, which are displaced, and form chlorohydric acid, which is disengaged, while the other three replace the hydrogen which is removed.

Frequently there is a partial displacement by which a new radical is formed, which combines in its nascent state with other elements. Thus alcohol is the hydrated oxide of ethule, $C_4H_5, O+HO$. When it undergoes the acetous fermentation it absorbs four atoms of oxygen from the air; two of them combine with two atoms of its hydrogen to form water, thus converting the ethule, C_4H_5 , into a new radical, acetule, C_4H_3 , which seizes in its nascent state upon the other two atoms of oxygen, to form acetic acid, which is a teroxide of acetule, C_4H_3, O_3 , and which retains the atom of water, originally contained in the alcohol, as it is incapable of existing except in combination with a base. So, likewise, when equal weights of acetate of potassa, and arsenious acid, are exposed to a dull red heat, a dense fuming liquid is obtained, which is the oxide of a new complex radical. This radical, which has received the barbarous name of *Kakodule*, is pro-

duced by the breaking up of the acetic acid, and is remarkable for containing metallic arsenic. Its formula is C_4H_4As . It unites with the electro-negative elements, forms an acid and a salifiable base, and is distinguished from every other series of the kind, by the insupportable odour and deadly poison of all its compounds.

463. The impossibility under which many of these organic products labour of separate existence, is a frequent cause of their decomposition. When a substance is presented to them which abstracts the base with which they are combined, they are decomposed in the act of separation into simpler and more permanent combinations. Thus oxalic acid, C_2O_3 , cannot be obtained in a purer form than its sesquihydrate; and when its crystals are heated with sulphuric acid, the water is abstracted, and the oxalic acid separates into carbonic oxide, CO , and carbonic acid, CO_2 .

464. When these organic products are subjected to the action of highly oxygenated bodies, such as nitric or chloric acid, or the peroxide of lead, or manganese, they always combine with the oxygen, and are reduced to simpler forms containing fewer atoms.

The oxygen, according as the action is more or less intense, converts more or less of the hydrogen into water, sometimes replacing a portion of that which it abstracts, and sometimes combining directly with the body itself. Thus when gum, $C_{12}H_{10}O_{10}$, is subjected to the action of nitric acid, it first converts two atoms of the acid into deutoxide, and seizing upon the disengaged oxygen, is converted into mucic acid, $C_{12}H_{10}O_{16}$. By increasing the heat, an additional portion of nitric acid is decomposed, all the hydrogen is converted into water, two additional atoms of oxygen enter into combination, and

the mucic acid is converted into six atoms of oxalic acid, $6\text{C}_2\text{O}_3 = \text{C}_{12}\text{O}_{18}$.

465. In other cases both bodies are decomposed or changed, and the resulting compounds combine to form a new product. Thus when olefiant gas, C_4H_4 , is subjected to the action of chlorine, an oily liquid is formed, which contains $\text{C}_4\text{H}_4\text{Cl}_2$. In this case the chlorine replaces an atom of hydrogen, which it converts into chlorohydric acid, and the two products combine, so that the true formula of the oily liquid is $\text{C}_4\text{H}_3, \text{Cl} + \text{HCl}$. So, likewise, when nitric acid acts on the substance called naphthaline, the composition of which is C_{20}H_8 , it is decomposed into nitrous acid and oxygen; the latter abstracts an atom of hydrogen, which is replaced in the compound by the atom of nitrous acid, and the product is $\text{C}_{20}\text{H}_7 + \text{NO}_4$. At the same time another atom of naphthaline is divided into two, each containing C_{10}H_4 , and the same change takes place in this new atom as in the old; a portion of the naphthaline being resolved into the new product, $\text{C}_{10}\text{H}_3 + \text{NO}_4$.

466. *Spontaneous changes in Organic Products.*—The stability, equally with the chemical energy of these organic products, varies greatly. Mere exposure to warm and moist air is in a large number of cases sufficient to induce decomposition. Those bodies which are most liable to this spontaneous change are the immediate constituents of vegetables, and animals, such as sap, blood, milk, and animal and vegetable fibres. When the vital principle, which is capable of preserving these for a long course of years, departs, the change at once begins. So slight are the affinities which hold them together, that the tendency of their elements to enter into simpler combinations soon develops itself; the hydrogen and nitrogen form ammonia; and the carbon and hydrogen seize upon the oxygen of the air, and form carbonic acid and water. A variety of fetid

gases, due to the presence of sulphur, phosphorus, &c., are disengaged, and the whole mass soon becomes putrid.

467. This putrefaction does not take place if the heat is sufficient to coagulate the albuminous fluids and to drive off the water, nor when the latter is congealed by cold. It is prevented also by the presence of salt, or of alcohol, which abstracts the water, and of reagents, such as corrosive sublimate, &c., which combine with the organic tissue, and render its affinities more stable.

468. This spontaneous change, which takes place rapidly under favourable circumstances, may be greatly prolonged by moderating its activity. It then becomes, in fact, a slow combustion, in which only the more combustible element is slowly consumed. Such is the mouldering decay which wood undergoes, in which the greater part of the hydrogen, and a portion of the carbon, are burnt out, while the organic texture is destroyed, and a pulverulent carbonaceous mass remains—the vegetable mould or *humus*, so fertilizing to the soil.

469. *Starch, Gum, Sugar.*—The most abundant products of vegetable secretion, are starch, gum, and sugar. Their composition is nearly the same, being twelve atoms of carbon united with varying quantities of oxygen and hydrogen in their atomic proportions. Thus the composition of starch, and of gum, is $C_{12}H_{10}O_{10}$, of sugar from the sugar cane, $C_{12}H_{11}O_{11}$, or $C_{12}H_{10}O_{10} + Aq$, and of sugar from grapes, $C_{12}H_{12}O_{12}$, or $C_{12}H_{10}O_{10} + 2Aq$. The forces which hold these atoms together, are so nearly balanced by the divellent affinities, that slight causes are sufficient to effect their transformation into new compounds, and the conversion of all the others into sugar of grapes.

470. *Ferments.*—The transformation which grape sugar itself, in certain circumstances, undergoes, is

one of the most remarkable phenomena in chemistry. When the air is entirely excluded, its solution remains without change; but with the free access of the air, it obeys the ordinary law of organic decay, loses its sweetness, and becomes discoloured, sour, and fetid. There is a substance well known by the name of yeast or *ferment*, which is the scum that collects on the surface of fermenting beer. Let a small portion of yeast be added to the solution of sugar, kept at a temperature of 70° or 80° in a close glass vessel, and let a tube pass from the vessel to a pneumatic apparatus containing mercury, so that all the gaseous products can be collected. In a short time the mixture becomes turbid; minute bubbles of gas begin to collect; the temperature and the internal agitation increase, and then gradually subside, and the solution again becomes cool and clear.

471. If we now examine the products, we shall find that a quantity of carbonic acid gas has been collected over the mercury, and that the liquid has lost all the properties of sugar, and is converted into a new substance, *alcohol*. The change which has thus taken place, is a mere transformation of the elements of the sugar. Grape sugar consists of $C_{12}H_{22}O_{11}$, alcohol of $C_4H_6O_2$, and carbonic acid of CO_2 ; so that each atom of sugar has been converted into two of alcohol and four of carbonic acid.

472. Although nothing has been either gained or lost in this process, the presence of ferment is essential to the change. What then is the nature of its agency?

Yeast consists chiefly of gluten—a vegetable principle containing much nitrogen; and it is efficacious as a ferment only when it is itself in an active state of decomposition. The internal agitation of its particles is then sufficient, when it is diffused throughout the saccharine liquid, to overcome the *vis-inertiæ* of the forces by which the elements are held to-

gether as sugar, and to induce new arrangements by which stronger affinities come into play. This molecular agitation is propagated from the yeast to the adjoining particles of sugar, and from these, particle by particle, throughout the whole mass, till the decomposition is complete.

473. This force, by means of which the presence of one body brings about, in the chemical arrangements of another, a change altogether disproportioned to the relative quantities and ordinary reaction of the bodies, has received the name of *catalysis*, and has been supposed, without sufficient foundation, to be a new and anomalous power. In the present case, the principle on which the change takes place, is precisely like that which governs the cases before noticed, in which a decomposition, begun in a single particle, is propagated throughout the whole mass, by the disturbance of the equilibrium of forces which had maintained the atoms of the compound in a quiescent state.

474. This power, which bodies in a state of decomposition possess, of inducing the same state in those with which they come in contact, is the cause of many of the transformations which occur among organic products.

CHAPTER II.

THE COMPOUNDS OF CARBON WITH ELECTRO-NEGATIVE ELEMENTS.

SECTION I.

CARBON AND OXYGEN.

475. *Carbonic Oxide.* CO ; $6.12 + 8 = 14.12$. This oxide may be prepared by heating to a red heat in a gun-barrel, a mixture of two parts of well dried

chalk (carbonate of lime) and one part of pure iron filings. The gas which is evolved must be collected over water, and will be found to be a mixture of carbonic acid and carbonic oxide. The former is readily absorbed by the water, leaving the latter pure. Carbonic oxide may also be prepared by heating in a glass retort, one part of binoxalate of potassa, oxalate of ammonia, or oxalic acid itself, with five or six times its weight of sulphuric acid. In the former process the iron is oxidated by the abstraction of an atom of oxygen from the carbonic acid which is thus resolved into carbonic oxide. The carbonic acid gas which comes over is evolved by the decomposition of the carbonate of lime. In the latter case the oxalic acid is resolved into carbonic acid and carbonic oxide, by the action of the sulphuric acid.

Carbonic oxide is a colourless, tasteless, inflammable gas, which is sparingly absorbed by water, and has no action on earths or alkalies.

When a lighted taper is plunged into a jar full of this gas, the taper is extinguished after setting fire to the gas, which burns quietly with a pale blue flame. Carbonic oxide gas is highly deleterious to the animal system; taken into the lungs it occasions headache, and when breathed pure, almost instantly produces stupor.

The specific gravity of carbonic oxide gas is .9727. A mixture of 100 measures of this gas and 50 measures of oxygen explodes by the electric spark, and is converted into 100 measures of carbonic acid.

476. *Oxalic Acid.* C_2O_3 ; $12.24 + 24 = 36.24$. This acid is evolved in the process of vegetation, and exists in combination with potassa, in the *rumex acetosa*, and the *oxalis acetosella*, or sorrel, from which last plant it has derived its name. It also exists in combination with lime in several species of lichen. Oxalic acid may be prepared artificially by

digesting sugar in five or six times its weight of nitric acid, and distilling off the excess of acid; the residue, on cooling, yields crystals of oxalic acid which amount to about one half the weight of the sugar. The acid may be prepared from many other organic substances, as gum, starch, wool, hair, and silk.

Oxalic acid has a very sour taste, reddens vegetable blues, and forms neutral salts. It crystallizes in slender flattened four or six sided prisms, with di-hedral summits, the primary form of which is an oblique rhombic prism. These crystals are a compound of one atom of acid, and three atoms of water, two of which escape when they are heated to 212° ; they are permanent at common temperatures, but effloresce in a higher temperature, fuse in their own water of crystallization at 209° , and dissolve in 15.5 times their weight of water at 50° . They are also soluble in alcohol. Oxalic acid evaporates very slowly at common temperatures, and when heated to 330° it sublimes rapidly and condenses in transparent acicular crystals, which contain one atom of water.

Oxalic acid is a rapid and fatal poison, the proper antidote for which is a mixture of chalk and water.

Oxalic acid may be distinguished from all other acids by its form of crystallization, and by its forming with lime a white precipitate insoluble in an excess of acid.

477. *Carbonic Acid.* CO_2 ; $6.12 + 16 = 22.12$.—Carbonic acid may be prepared by decomposing fragments of marble, (carbonate of lime,) with diluted chlorohydric acid, and collecting the gas over mercury. Carbonic acid is an invisible inodorous gas, which is condensed beneath a pressure of 36 atmospheres into a transparent colourless fluid. This fluid is the most expandible body known; at 32° its sp. gr. is .83, and its expansion is nearly

one per cent for each degree of Fahrenheit, which is four times that of air. If a jet of the liquid acid be directed into a small cylindrical vessel, the cold produced by the sudden conversion of one part into gas, will be sufficient to congeal the remainder into a soft snow-like mass, which evaporates very slowly.

478. Carbonic acid gas is incombustible; it extinguishes all burning bodies except potassium, and destroys animal life when it forms only a fourth part of the atmosphere. When an attempt is made to breathe carbonic acid it causes a violent spasm of the glottis which prevents the air from entering the lungs. If the gas be so much diluted with common air that it can be breathed, it acts as a narcotic poison and proves speedily fatal to life. Its sp. gr. is 1.524.

479. The liquid differs from the gaseous carbonic acid in a very remarkable circumstance. The former mingles in all proportions with ether and alcohol, but not with water, on the surface of which it floats like oil. On the other hand carbonic acid gas is readily diffused through water, which will take up its own bulk at the common atmospheric pressure. The quantity of the air compressed into the water is in exact proportion to the pressure, and the gas escapes as soon as that pressure is removed. These phenomena closely resemble those caused by the mutual indifference and penetration of the gases. Carbonic acid and water are mutually indifferent, and the presence of the latter, like that of a gas, is no obstacle to the diffusion throughout its mass and between its particles, of the former. When both materials are in a liquid state, the attraction of gravitation separates them, and the lighter fluid floats above the heavier.

480. The artificial Seltzer waters sold in the

shops, are prepared by forcing into a strong metallic vessel, containing water, six or eight times its volume of carbonic acid gas. The effervescence of these waters, and their pleasant acidulous taste, are owing to the presence and escape of the acid. It is to the presence of the same acid, evolved during the vinous fermentation, that beer, cider, and sparkling wines, owe their agreeable pungency.

Water, holding carbonic acid in solution, reddens litmus paper; the acid is expelled by boiling, or by removing the atmospheric pressure. Carbonic acid may be distinguished from other acids by forming a precipitate with lime water, which effervesces when mixed with any other acid.

Carbonic acid is extensively diffused throughout nature. It always exists in the atmosphere, and in natural waters; it is evolved in the process of respiration, vegetation, and fermentation; it is discharged in great quantities from fissures in the earth, and from springs of water in certain volcanic regions; and in combination with lime and other metallic oxides, it forms a large portion of the earthy and rocky crust of the globe.

481. *The Carbonates.*—The carbonates are decomposed with effervescence by nearly all the acids. Most of them part with their acid when heated to dull redness; the carbonates of lime and magnesia are decomposed at a full red heat, those of baryta and strontia at an intense white heat, and those of potassa, soda, and lithia, are unalterable in the fire. When the carbonate of lime is subjected to an intense heat, under a very great pressure, it fuses, without decomposition, into a crystalline mass. Excepting those of the alkalis, the carbonates are sparingly soluble in water.

482. The carbonate of potassa is procured from the ashes of vegetables by lixiviation and evapora-

tion, and is known by the names of potash and pearlash. In this state it always contains other salts, chiefly the sulphate of potassa and chloride of potassium. A pure carbonate of potassa is obtained by heating the bitartrate of potassa to redness. A mixture of charcoal and pure carbonate is left, from which the latter may readily be obtained by solution in water. It may thus be obtained in crystalline grains, and in this state it is called salt of tartar.

Pure carbonate of potassa has a strong alkaline taste, turns vegetable blues green, and is slightly caustic. It is highly deliquescent, dissolves in less than its weight of water at 60° , and crystallizes with difficulty from its solution. It fuses at a full red heat, and is insoluble in alcohol. Its principal uses in the arts are in the manufacture of soap and glass.

When a current of carbonic acid gas is passed through a solution of the carbonate of potassa, a bicarbonate is formed, which crystallizes in octohedral prisms, requires four times its weight of water at 60° to dissolve it, and does not deliquesce.

483. The carbonate of soda is obtained by lixiviating the ashes of sea weeds, and when thus made is called kelp and barilla. It is also prepared by decomposing the sulphate of soda at a red heat by a mixture of sawdust and lime. Sulphuret of calcium and carbonate of soda are formed, and the latter is obtained by lixiviation and crystallization. Carbonate of soda has an alkaline taste, and turns vegetable blues green; it crystallizes in octohedrons with a rhombic base, containing either 7 or 10 atoms of water. Its crystals effloresce in the air; when heated they fuse in their own water of crystallization, and dissolve in about two parts of cold water.

484. A sesquicarbonate of soda is found native in central Africa, being contained in the waters of certain lakes which become dry in summer. It is called

trona, whence one of the names of soda, *natron*, is derived.

By passing carbonic acid gas through its solution, the carbonate is converted into a bicarbonate, a less soluble and less alkaline salt.

The carbonate of lime is one of the most abundant salts in nature. Chalk, marble, limestone, are carbonates of lime; and it is the principal material of the shells of molluscous animals. The form of its primitive crystal is a rhomboid, and the number of its secondary forms exceeds two hundred.

The protocarbonate of lead is the common pigment called white lead.

The bicarbonate of lime and magnesia is a native crystalline limestone rock, known by the name of dolomite.

485. Carbon forms three other acids with oxygen, the rhodizonic, which is a tribasic acid, its composition being $C_7O_7 + 3Aq$, or $C_7O_{10} + H_3$; the croconic acid, $C_5O_4 + Aq$, or $C_5O_5 + H$; and the mellitic acid, $C_6O_3 + Aq$, or $C_6O_4 + H$. It is highly probable that carbonic oxide is the real base of all these compounds. In this case oxalic acid will be represented by $2CO + O$, and carbonic acid by $CO + O$.

Carbonic oxide also unites as a base with chlorine to form what is called the chlorocarbonic acid, $CO + Cl$, the phosgene gas of Davy.

SECTION II.

CARBON AND THE SALT RADICALS.

486. The chloride, bromide, and iodide of carbon, are volatile, aromatic, crystalline solids, or transparent liquids, analogous to camphor and the essential oils in their properties.

SECTION III.

CARBON AND SULPHUR.

487. *Sulphocarbonic Acid. Bisulphuret of Carbon.* — $C S_2$; $6.12 + 32.2 = 38.32$. This acid may be prepared by passing the vapour of sulphur over fragments of red-hot charcoal, in a porcelain tube, and collecting the vapour under water. It is a transparent, colourless liquid, remarkable for its high refractive power. Its sp. gr. is 1.272; it has an acid, pungent, slightly aromatic taste, and a highly fetid smell, resembling that of putrid cabbages. It is very volatile, boils at 110° , and produces intense cold during its evaporation. It is very inflammable, and burns with a pale blue flame. It is soluble in alcohol and ether, and dissolves sulphur, phosphorus, and iodine, forming a beautiful pink solution with the latter.

488. This acid forms true sulphur salts with the metallic protosulphurets; and their composition is such, that if the sulphur be replaced by oxygen, the corresponding carbonates will be formed.

CHAPTER III.

THE NON-NITROGENOUS COMPOUNDS OF CARBON AND HYDROGEN.

489. We shall gain a clearer view of the subject of organic chemistry, by tracing its products from their more complex to their simpler forms, as we shall thus follow the progress of discovery, and throw into natural groups a variety of compounds, of which the theoretical relations are not well understood.

The organic radicals are conveniently divided into two classes, the nitrogenous and non-nitrogenous—the latter embracing most vegetable, and the former most animal products. The only ones which contain no carbon are amide, and its derivatives.

SECTION I.

THE ALCOHOLIC SERIES.

490. *Starch, Lignine, Gum, and Sugar.*—These substances are the most important and abundant vegetable secretions. They are formed in all plants, and may be regarded as the stores laid apart by the plant itself for its own future nutriment. They are classed together on account of their close resemblance in constitution and properties, being all formed of twelve atoms of carbon, combined with oxygen and hydrogen in the proportions to form water; and being easily convertible into the same product.

491. Starch and lignine possess an organic structure, which they retain until decomposed. Starch is imbedded in the cellular tissue of plants, as small white grains of an irregular form. Each grain consists of concentric layers, the outer ones of which are the most hard and insoluble, so that when the grain is crushed, it becomes a soft mass. It is readily procured from plants which contain it, by reducing them to a powder, and washing away the soluble parts with cold water. The fecula subsides in the form of a white powder. It is insipid, inodorous, and insoluble in alcohol, ether, and cold water. When, however, the grains of fecula are triturated in a mortar, so as to bruise and break the outer covering, the inner portion, which is soluble, being exposed, a partial solution in cold water may be effected. Boiling water readily dissolves fecula, con-

verting it into a tenacious, bulky jelly, which forms when dry a solid of a horn-like transparency, which retains its solubility in cold water.

Starch, like sugar, forms definite soluble compounds with the alkalies, and insoluble ones with the alkaline earths and oxide of lead. It is decomposed by the action of sulphuric and nitric acid, being converted by the latter into oxalic and malic acids. The most delicate test of the presence of starch is iodine, which colours its solution blue.

When heated a little above 212° , fecula acquires a slightly red tint, the odour of burnt bread, and becomes soluble in cold water. The term amidine is applied to starch which has, either thus, or by being dissolved in hot water, been rendered soluble in cold water.

When starch is heated still higher it assumes a dark colour, swells and softens, and becomes very similar to gum in its properties. In this state it is employed by calico printers, under the name of British gum.

492. Fecula is readily converted into sugar. This change takes place in the germination of seeds, and may be effected by frost and by the action of dilute sulphuric acid. If starch is boiled for a considerable time in water, acidulated with $\frac{1}{12}$ th of its weight of sulphuric acid, it is wholly converted into sugar, identical with the sugar of grapes. 100 parts of starch yield 110 of sugar, and the only difference in their composition is, that sugar contains a greater proportion of the elements of water. The agency of sulphuric acid in effecting this change appears to consist in furnishing the required water; for it does not itself suffer any diminution in the process.

The composition of fecula, or starch, is $C_{12}H_{10}O_{10}$.

493. A variety of starch called *Inuline*, is obtained in the same manner as common starch from the roots

of the Elecampane, Dahlia, &c. Its solution in hot water does not gelatinize as it cools, but deposits its inuline unchanged. Another variety is found in the Iceland moss, which is soluble in cold water. Their composition is the same as common starch.

494. Lignine, or woody fibre, constitutes the fibrous structure of vegetable substances, and is the most abundant principle in plants. It is prepared by digesting sawdust in alcohol, water, and dilute chlorohydric acid, until it ceases to yield any soluble matter to these menstrua.

Lignine has neither taste nor odour, is unalterable in the air, and is insoluble in alcohol, water, and the dilute acids. By the action of strong sulphuric acid, it is converted into gum, which is again changed by long boiling into a saccharine substance, identical with sugar of grapes.

Lignine has a strong affinity for alumina, oxide of iron, and of tin, and will separate them from their combinations. When precipitated upon the vegetable fibre, these compounds can be combined with various colouring matters, which may thus be fixed permanently on the fibre. When paper, which is pure lignine, is immersed in strong nitric acid, and immediately well washed, it becomes thick and tough like parchment, and so combustible as to serve for tinder. The composition of lignine is $C_{12}H_8O_8$.

495. Gum is a concrete juice, which exudes principally from the bark of many trees, and also from other parts of the plant.

Pure gum is colourless, transparent, inodorous, insipid, brittle, and breaks with a vitreous fracture. It has a strong affinity for water, and forms in that liquid a clammy, adhesive solution. It is insoluble in ether and alcohol, and is precipitated by the former from its solution in opaque white flakes. Its solubility is increased by acids and alkalies, and it is

converted, when heated with strong nitric acid, into a peculiar acid, called the mucic acid. Gum forms definite insoluble compounds with several of the metallic oxides, especially that of lead. The solution of the dinacetate of lead is therefore the most delicate test of the presence of gum.

The purest specimen of gum is gum-arabic, the concrete juice of the mimosa, an African tree. It is soluble in cold water; and the name of *Arabine* has been proposed for this species. Another species of gum exudes from the bark of the cherry, peach, and apricot. It is insoluble in cold water, but soluble in boiling water, and is identical in composition with arabine. It is distinguished by the name of *Cerasine*. A third species, Bassora gum, is called *Bassorine*; it swells into a jelly in hot water, but does not dissolve. The mucilage of flaxseed, and that from the bark of the slippery-elm, appear to form another species or variety of gum. Gum tragacanth is a combination of arabine and bassorine.

The composition of gum is $C_{12}H_{10}O_{10}$.

496. *Cane Sugar*.—Cane sugar exists abundantly in the sap of certain vegetables, more especially in that of the sugar cane, the sugar maple, and the root of the beet, from all which it is extensively manufactured.

Pure sugar is white, hard, brittle, inodorous, and intensely sweet. Its sp. gr. is 1.6, and it fuses at 350° into a clear yellow liquid. It crystallizes in four or six sided prisms, which are bevelled on their edges. It is soluble in its own weight of cold, and to almost any extent in hot water, and in four times its weight of boiling alcohol. It forms definite crystalline soluble compounds with alkalies and alkaline earths and common salt, and an insoluble one with oxide of lead, thus acting the part of a feeble acid.

497. Sugar is inflammable, and is much altered by exposure to heat, acquiring a dark colour and an

empyreumatic taste. It is then called *caramel*. The composition of cane sugar is $C_{12}H_{11}O_{11}$. Strong nitric acid converts it into oxalic acid; by the action of dilute nitric acid, it is converted into a pentebasic acid—the saccharic acid, the crystals of which consist of $C_{12}H_5O_{11} + 5HO$, and its constitution must be regarded as $C_{12}H_5O_{11} + H_5$.

498. *Glucose—Sugar of Grapes.*—This species of sugar is the saccharine principle of grapes, and of most sweet fruits. It is also copiously secreted in certain diseases, such as diabetes, and is formed from starch in the process of germination, and from all the preceding compounds by artificial processes. It crystallizes in cubes, or in flat quadrangular tables, or in minute needles. Its sp. gr. is 1.38, and it is less sweet and soluble than cane sugar. It is converted into caramel by heat, and forms definite compounds with metallic oxides. Its composition when crystallized is $C_{12}H_{11}O_{11} + 3Aq$, and when fused at 212° , $C_{12}H_{11}O_{11} + Aq$, or $C_{12}H_{12}O_{12}$. As the above compounds differ from each other only in the quantity of the elements of water, we can readily understand the ease with which they are converted into sugar of grapes.

499. Lignine is converted into grape sugar by macerating in the cold, 12 parts of linen or paper shreds, with 5 of oil of vitriol, and one of water. After 24 hours the mass is dissolved in a large quantity of water, and boiled for ten hours. It is then neutralized with chalk, and evaporated.

500. Starch is converted into grape sugar by moistening its paste with a solution of pale malt, and keeping the mixture at 160° or 170° for several hours. Six parts of malt will produce 2.5 of sugar. This change is effected by the action of a peculiar ferment, namely, the substance called *diastase*, which is formed in barley in the process of malting, and which can be obtained from it in the form of a gum-

my, tasteless, white mass. It acts only when in a state of active decomposition, and disturbs the equilibrium, so as to induce a new arrangement of the particles of the starch. One part of diastase is sufficient to convert in a few hours 2000 parts of starch into sugar, if the temperature do not exceed 168° .

This change is also effected by boiling one part of starch with four parts of water, and $\frac{1}{10}$ th of sulphuric acid, during 36 or 40 hours; taking care to renew the water as it evaporates. It is not easy to point out the manner in which the sulphuric acid acts; but the change is evidently due to the fixation in the gum and cane sugar of one atom, in starch of two, and in lignine of four additional atoms of water.

501. Before being converted into grape sugar, starch is converted into a species of gum called dextrine, which is isomeric with itself, and which is speedily changed into sugar.

502. *The Vinous Fermentation.*—The changes which take place in the solution of grape sugar when it undergoes the vinous fermentation, have already been detailed. There is reason to believe that it is the only substance capable of that change, and that cane sugar becomes converted into it before fermentation takes place. The substances which excite the vinous fermentation all agree in containing a large portion of nitrogen, and in entering readily into that state of decomposition, which they communicate to sugar. Ripe saccharine fruits contain this principle, and their juices, therefore, spontaneously enter into the vinous fermentation whenever the temperature is favourable.

503. *Alcohol.*— $C_4H_6O_2=46.48$. The alcohol which is the product of this fermentation, may be separated from the water, gum, sugar, and other principles, with which it is usually associated, by repeated distillations; the last of which must be from dry carbonate of potassa, or chloride of calcium.

Pure or absolute alcohol is a colourless, limpid fluid of a penetrating odour, and hot, burning taste. It is highly volatile, of the sp. gr. of .795, boils at 168° , and has never been congealed. It is very inflammable, and burns with a lambent, yellowish-blue flame, without smoke. It unites with water in every proportion, heat is evolved, and the mixture occupies less space than did the alcohol and water it contains. Alcohol dissolves the resins, the essential oils, the alkalies, and the deliquescent salts. The latter crystallize from their alcoholic, in the same manner as from their aqueous solution, in combination with alcohol of crystallization. The term *alcoate*, is applied to these definite crystalline compounds.

From its greater affinity for water, alcohol precipitates gum, and the efflorescent salts, from their aqueous solution.

504. *Ether*.— $C_4H_{10}O$. This substance differs from alcohol by containing one atom less of water, and may be prepared from it by any process which will deprive it of that atom. It is usually obtained by the action of oil of vitriol on its own weight of alcohol. The mixture is quickly raised to the temperature of 260° , when it boils, and the ether distils over, mingled with water and alcohol, from which it is freed by a second distillation. In this process the oil of vitriol, and alcohol, both part with their water, and anhydrous sulphuric acid combines with ether to form sulphate of ether. This sulphate combines with another atom of oil of vitriol, and forms the bisulphate of ether, or sulphovinic acid, $C_4H_8O + SO_3 + SO_3 + Aq$. When this product is heated to 260° it is decomposed; the ether escapes in the form of vapour, and the sulphuric acid re-combines with water.

505. Pure ether is a colourless, limpid fluid, of a hot, pungent taste, and fragrant odour. Its spe-

cific gravity is .7; it is very volatile, boiling at 96° , and at -40° in a vacuum. At -46° it congeals, and its evaporation in a cool atmosphere is sufficient to freeze mercury. It combines with alcohol in all proportions, but is sparingly soluble in water. It is highly inflammable, and burns with a bright white flame. It dissolves the essential oils, resins, and fatty matters, but the fixed alkalies are insoluble in it. When a coil of platinum wire is heated to redness, and suspended over the surface of ether in an open vessel, it sets fire to the stratum of vapour immediately around it, and is kept at a red heat by the combustion until the ether is consumed.

Phosphoric acid acts on alcohol in the same manner as sulphuric, forming a phosphovinic acid, which is subsequently decomposed; and the ethers which the two acids form, are identical in composition and properties.

506. Ether combines with almost all the acids, forming compounds which constitute a very natural and distinct group of the family of salts. These ethereal salts are generally volatile, aromatic fluids, freely soluble in oil and alcohol, and more or less in water, although some of them are crystalline solids. The hyponitrite of ethule is the nitrous ether, and its alcoholic solution, the sweet spirits of nitre of the shops, a highly fragrant, sweet, volatile fluid, much used in medicine.

507. The salt radicals displace the oxygen of the protoxide of ethule, and form compounds possessing all the generic properties of the ethers. These phenomena are to be explained by regarding ether as the protoxide of an organic radical, C_4H_5 , which has received the name of ethule, and which acts the part in composition of an electro-positive element. According to this view, the composition of ether is C_4H_5 , O, and of alcohol C_4H_5 , O+HO.

Ethule, ether, and alcohol, are the types of seve-

ral series of organic compounds in which the oxides, and the hydrated oxides of compound radicals, possess properties closely allied to those of ether and alcohol.

508. *Other products of the decomposition of Alcohol.*—When six measures of oil of vitriol are strongly heated with two of alcohol, the mass becomes dark, boils rapidly, and finally swells and blackens, and a mixture of various vapours and gases is copiously evolved. By agitation with water, the condensible products, which are sulphurous acid, ether, and vapour, are removed, and a gas remains which is colourless, of an ethereal odour, highly inflammable, and burning with a brilliant white flame and with much smoke. This gas is the olefiant gas, or heavy carbureted hydrogen gas of chemists. It detonates violently by means of the electric spark, when mixed with three or four times its volume of oxygen gas. For each measure of olefiant gas, three measures of oxygen disappear, water is deposited and two measures of carbonic acid gas are formed. These two measures of carbonic acid consist of two of oxygen and two of vapour of carbon. The remaining volume of oxygen combines with two volumes of hydrogen to form water; so that olefiant gas contains two volumes of vapour of carbon and two of hydrogen condensed into one, and its sp. gr. is therefore .9868. Its atomic constitution is $C_2H_2=14.24$, or according to others, $C_4H_4=28.48$.

509. If a jar of olefiant gas be inverted in a pneumatic trough, and bubbles of chlorine be passed up into it, both gases disappear, and a heavy oily liquid is formed, which may be collected in a cup beneath the mouth of the jar. When pure, this liquid is colourless, of a sweet ethereal odour, and inflammable. It consists of $C_4H_4Cl_2$, and is decomposed by an alcoholic solution of potassa, which

abstracts an atom of chlorohydric acid, forming chloride of potassium, and a gas having a garlic odour, and burning with a smoky red flame. The composition of this gas is C_4H_3Cl ; so that the oily liquid is the chlorohydrate of this substance, and must be represented by $C_4H_3Cl + HCl$.

510. *Acetule*.—The chlorine has therefore in decomposing the olefiant gas, formed a new radical, C_4H_3 , with which it has combined, forming the chloride, $C_4H_3 + Cl$. This radical has received the name of *acetule*, and is formed from alcohol by other processes.

511. *Aldehyde*.—When alcohol is exposed to the action of substances which enable it to combine with oxygen, it parts with two atoms of its hydrogen, and is converted into a liquid called aldehyde, a neutral, inflammable, aromatic fluid, which mixes with water, alcohol, and ether. The composition of aldehyde is $C_4H_4 + O_3$, and it bears the same relation to acetule that alcohol does to ethule; that is to say, it is its hydrated oxide, and its composition is represented by the formula $C_4H_3, O + Aq$.

512. *Acetic acid*.—If the oxidizing process be continued, aldehyde combines with two additional atoms of oxygen, and is converted into acetic acid, of which the formula is $C_4H_3O_3 + HO$.

When any fermented liquor is exposed to the free access of air at the temperature of 60° or 80° , an intestine motion of the particles takes place, the liquid becomes turbid, absorbs oxygen, and in the end, all the alcohol is found to be converted into acetic acid. This acetous fermentation takes place with a rapidity proportioned to the free access of air; and the changes through which the alcohol passes are those which have been recited above; aldehyde being always a product intermediate between the alcohol and the acetic acid. The change is due, in all cases, to the presence of a decomposing ferment, which disturbs the equilibrium of the par-

ticles of the alcohol so as to bring new affinities into play.

The most concentrated acetic acid which can be prepared is the hydrated acid, $C_4H_5O_4 + HO$. It crystallizes at 50° and boils at 240° ; it has a peculiar aromatic pungent odour, and a caustic taste; it blisters the skin, mixes with water, alcohol, and ether, and dissolves camphor and the essential oils. Its specific gravity is 1.063; by diluting with water it acquires the sp. gr. of 1.078, and is then a definite compound of the acid, with two additional atoms of water. Further dilution reduces its specific gravity so that an acid containing 64 per cent. of water has the same specific gravity as the most concentrated.

513. *The Acetates*.—Acetic acid forms salts which are all soluble in hot, and most of them in cold water, and which are decomposed by sulphuric acid with the evolution of acetic acid. The acetate of copper is the pigment called verdigris; the acetate of lead, the well known salt, sugar of lead.

514. *Pyroligneous Acid*.—A pure acetic acid known by this name is prepared in considerable quantities by the destructive distillation of wood in close vessels. It is obtained mingled with tar, empyreumatic oils, water, pyroxylic spirit, &c., from which it is freed by being neutralized by carbonate of lime; the acetate of lime precipitates and is decomposed by sulphate of soda; the acetate of soda which is thus formed, is fused to free it from empyreumatic oils, and is then redissolved and crystallized, and decomposed by oil of vitriol.

515. *Pyroxylic Spirit*.—If the liquid from which the acetic acid in the above process, has been separated by carbonate of lime, be distilled, a spirituous liquid, termed pyroxylic spirit, is obtained, which closely resembles alcohol. Pure pyroxylic spirit is a colourless aromatic liquid, resembling in smell

and taste both alcohol and acetic ether. It burns with a paler flame than alcohol, its sp. gr. is .798; it boils at 140° , mixes perfectly with water, alcohol, and ether, dissolves the resins and essential oils, and is a true alcohol. When treated with sulphuric acid it produces an ether, an acid, and a heavy ethereal oil, in the same manner as alcohol.

516. *Methule*.—These phenomena are explained by the supposition of an organic radical called methule, the formula of which is C_2H_3 .

Methylic ether will be represented by $C_2H_3 + O$. It is a colourless gas of an ethereal odour, highly inflammable, and burning with a blue flame. It is eagerly absorbed by water, and is isomeric with alcohol, but having half its atomic weight.

Pyroxylic spirit is the hydrated oxide of methule, and is represented by $C_2H_3O + HO$. Methule combines with the electro-negative elements, and its oxide, with the acids, forming a series of compounds perfectly analogous to those of ethule.

517. *Formic Acid*.—If the vapour of pyroxylic spirit be brought into contact with oxygen gas by means of spongy platinum, four atoms of oxygen are absorbed; two of them enter into combination with two of hydrogen, which the other two atoms of oxygen replace, and the pyroxylic spirit, $C_2H_4O_2$, is thus converted into two atoms of water and an atom of formic acid, $C_2H_2O_4$. This acid derives its name from existing in a very concentrated state in the common ant. It may be obtained by distilling a mixture of one part of starch, sugar, or tartaric acid, with four of black oxide of manganese, four of water, and four of oil of vitriol. Pure hydrated formic acid is a limpid colourless slightly fuming liquid, of the sp. gr. of 1.235. It boils at 212° , and congeals below 32° . In its most concentrated state it is exceedingly caustic. It forms crys-

talline salts, and when the formiates of many of the metals are heated, they are decomposed and the metal is revived.

518. *Formule*.—Formic acid is the oxide of a radical called formule, C_2H ; and its composition is $C_2H, O+HO$. This radical bears the same relation to methule which acetule does to ethule.

519. *Oil of Potato Spirit*.—There are many secondary products of the vinous fermentation of great interest to the chemist. Thus the peculiar flavour of wine is due to a species of ether, which is the only one that is a natural product. The flavour of spirit from grain is owing to a peculiar essential oil. From the spirit distilled from potatoes, an oil, which bears the name of oil of potato spirit, has been separated. This oil, like the pyroxylic spirit, is a genuine alcohol.

It is a colourless oily liquid, with an acrid taste, and an aromatic yet nauseous odour, soluble in ether and alcohol, and sparingly so in water, burning with a blue flame, having a specific gravity of .812, congealing at 4° , and boiling at 294° .

520. *Amule*.—The composition of this oil is $C_{10}H_{12}O_2$. Sulphuric acid forms with it an ethereal oil, and it is evidently the alcohol of a radical of which the formula is $C_{10}H_{11}$, and to which the name of amyle, or amule, has been given. This radical combines with chlorine, and its oxide with salts, to form true ethers. Its hydrated oxide is the oil above described, the proper name of which is *amylic alcohol*. By exposure to air this alcohol absorbs four atoms of oxygen, and loses two of hydrogen, being converted into an acid, $C_{12}H_{10}O_4$, identical with the valerianic acid, which exists naturally in the *valeriana officinalis*. This is an oily volatile acid, lighter than water, and forms soluble sweet-tasted salts.

521. *Cetule*.—There is a fourth radical of the

same family which forms an ether, an alcohol, a compound isomeric with olefiant gas, and an acid, precisely as in the above cases. This radical is called cetule; its constitution is $C_{32}H_{33}$; that of its ether $C_{32}H_{33}, O$, of its alcohol $C_{32}H_{33}, O+HO$, of its olefiant gas $C_{32}H_{32}$, and of its acid $C_{32}H_{31}O_3+HO$. This cetylic alcohol is obtained by the action of alkalies on spermaceti, and is known by the name of *Ethal*. It is a tasteless, inodorous, white crystalline solid, which melts at 119° , and volatilizes at 250° , is insoluble in water, burns like wax, and forms with sulphuric acid a compound analogous to sulphovinic acid.

The perfect parallelism of the compounds of these radicals, methule, ethule, acetule, and cetule, is one of the most remarkable and instructive facts, which the recent researches into organic chemistry have brought to light.

522. *Lactine—Sugar of Milk.*—There are other species of sugar which naturally belong under this head of the alcoholic series. Of these, lactine and mannite are the only ones necessary to be noticed.

Lactine, or sugar of milk, is a secretion found only in the milk of animals. It crystallizes in white semi-transparent square prisms—of a highly sweet taste, slowly soluble in water, and forming a very sweet syrup. These crystals contain $C_{34}H_{18}O_{11}+5Aq$, and are therefore isomeric with grape sugar, having double its atomic number. When heated to 300° , the sugar of milk fuses, and the 5 atoms of water are driven off. Dilute sulphuric acid converts it into grape sugar.

523. *Mannite.*—Mannite is a secretion from the inner bark of many trees. It is obtained from manna by the action of boiling alcohol, and crystallizes in shining acicular crystals. Its taste is sweet, it does not combine with bases, and its formula is $C_6H_7O_6$.

524. *Lactic Acid.*—When the juice of the beet,

or of the carrot root, which contains much sugar, is kept for some time at 100° , a genuine fermentation takes place, which is termed the viscous or mucous fermentation. Alcohol is not formed in this process, but all the sugar disappears, and gum, mannite, and lactic acid, are found in its place. The lactic acid which is thus formed, is copiously secreted in the living animal, and plays an important part in the changes which take place in the vital fluids. Pure concentrated lactic acid is a syrupy liquid of a strongly acid taste, the formula of which is $C_6H_8O_5 + HO$, and which is therefore isomeric with sugar of grapes, having half its atomic number. When heated to 480° , it parts with the elements of two atoms of water, and crystallizes in brilliant white plates, which may be purified by solution and crystallization from alcohol. Their constitution is $C_6H_4O_4$. Lactic acid is monobasic, and forms crystalline and soluble salts.

525. *Products of the decay of Lignine.*—When lignine is exposed to the action of air and moisture, its hydrogen slowly consumes, the vegetable structure becomes disintegrated, the proportion of carbon continually increases, and it is at last converted into vegetable mould, or into turf. The principal element of mould was originally obtained from the decomposition of the elm, and received the name of ulmine. It is also called humus, and geine, and the acid into which it passes by the action of alkalies, the ulmic, humic, and geic acid. These products are the elements which impart to vegetable mould its fertilizing qualities. Products closely allied to them are evolved by the action of cold dilute sulphuric acid upon starch, sugar, and lignine, and have received the names of sacchulmine, and sacchulmic acid. The formula of the former is $C_{40}H_{16}O_{14}$, and of the latter, $C_{40}H_{14}O_{12}$. A still longer action of a stronger acid converts these products into saccharohumine, $C_{40}H_{15}O_{15}$, and saccharohumic acid, $C_{40}H_{12}O_{12}$.

These are dark brown, or black substances, resembling ulmine and ulmic acid. If four atoms of lignine, $C_{48}H_{32}O_{32}$, combine with fourteen of oxygen, there will be given out $8CO_2$, and $18HO$; and an atom of ulmine or geine, $C_{40}H_{14}O_{12}$, will remain. The formula of the ulmic or humic or geic acid is $C_{40}H_{12}O_{12}$, being isomeric with the saccharohumic acid. This acid is insoluble in water, has a strong affinity for ammonia, and other alkaline and earthy bases with which it is combined in the soil. It is the opinion of Liebig, that it does not enter into the circulation of plants, but that its fertilizing properties are due to the ease with which it is decomposed, and the copious supply of carbonic acid it thereby furnishes.

526. *Light Carburetted Hydrogen Gas.*—When this decay of woody fibre takes place in shallow waters, a peculiar inflammable gas is disengaged, which consists of CH_2 , and is called light carburetted hydrogen, or marsh gas. It results from the decomposition of lignine by water, one atom of the former, $C_{12}H_8O_8$, combines with four of the latter, and yields $6CO_2$, and $6CH_2$. This gas may also be formed by heating to redness in a glass retort equal parts of acetate of potassa and caustic potassa. The acid and water are simultaneously decomposed, $C_4H_3O_3$, and HO , producing $2CO_2$, and $2CH_2$; the carbonic acid is absorbed by the potassa, and pure light carburetted hydrogen is evolved. It is a colourless, transparent, inflammable gas, burning with a yellow flame, and forming, with oxygen, a highly explosive mixture. It consists of 100 measures of vapour of carbon, and 200 of hydrogen, condensed into 100, and its sp. gr. is .5593.

527. This gas is occasionally disengaged in vast quantities in coal mines, and forms a highly explosive mixture by mingling with the atmospheric air. It constitutes the fire-damp of the miners, and has

occasioned the most disastrous accidents to those engaged in mining for coal. The frequent occurrence of the most melancholy disasters, drew the attention of Sir Humphrey Davy to the investigation of their cause, and the result of his experiments forms one of the proudest triumphs in the annals of science.

Sir Humphrey commenced his inquiries by determining the best proportions of air and of light carburetted hydrogen for forming an explosive mixture. This he found to be one of the latter to seven or eight of the former. In proportion as the relative quantity of either is increased, the mixture detonates more feebly, and ceases to explode when the air does not form more than three or four times the volume of the inflammable gas. On the other hand, the mixture continues to be feebly explosive when the volume of the air is increased to fourteen times that of the gas; while, if the proportion be still further increased, a taper burns in it with only an enlarged flame.

528. Davy next ascertained the temperature required for causing an explosion. He found that the strongest explosive mixture may be brought into contact with iron, and other solid bodies, heated to a red and even to a white heat, without detonating, provided the solid body is not in a state of combustion, whereas the smallest point of flame instantly causes an explosion. The cause of this difference is, that the temperature necessary to produce flame is far higher than the white heat of solid bodies; for flame is gaseous matter, heated so intensely as to be luminous.

Such being the nature of flame, it follows that rapid cooling will immediately extinguish it. Davy observed that flame is always extinguished in the passage through a narrow tube. He found that the narrower the tube, the shorter it may be to produce

this effect; and that a plate of brass, pierced with a great number of small holes, so as to present in fact an assemblage of fine tubes, effectually prevented the passage of flame. The gas itself passed, but was so much cooled by its contact with the metallic surface, as to be no longer luminous.

529. *The Safety Lamp*.—A piece of fine wire gauze was substituted for the plate, and was found to be equally impermeable to flame, and this led to the construction of the *safety lamp*. This simple contrivance is a common oil lamp, completely surrounded by a cage of wire gauze. It not merely prevents explosion, but indicates the precise moment of danger; for when it is carried into an atmosphere charged with the fire-damp, the flame begins to enlarge, and when the mixture becomes highly explosive, it takes fire as soon as it has passed the gauze, and burns on its inner surface, while the light in the centre of the lamp is extinguished. The wire gauze becomes heated to a red and even to a white heat, but does not allow the flame to pass. As soon as this appearance is observed, the miner must withdraw; for the gauze, which is generally made of iron or brass wire, would become oxidated in a few minutes, and fall to pieces.

This beautifully simple and effectual contrivance has been the means of preserving the lives of thousands. The only case in which it has been found to fail has been that of a rapid current of air carrying the flame through the gauze before it was cooled below the luminous point. This is effectually prevented by surrounding the common safety lamp with a glass cylinder, and allowing the air to enter through a fine wire gauze at the bottom of the cylinder, and to escape through another at the top.

530. *Mineral Coal*.—Bituminous coal is the result of the decomposition of wood under circumstances which do not allow of the escape of the carburetted

hydrogens which are formed, and which are therefore retained by, or compressed among, the particles of the carbon. When bituminous coal is exposed to the destructive distillation, these are evolved in the shape of tar and bitumen, and, when the heat is sufficiently great, of gaseous products consisting of various proportions of olefiant gas, light carburetted hydrogen, and carbonic oxide gases. The gas which is prepared by the decomposition of coal in close vessels, for the purpose of illumination, is a varying mixture of these gases. The composition of bituminous coal is $C_{32}H_{12}$. When the heat to which the coal has been exposed in the interior of the earth has been sufficiently great, all the hydrogen is expelled, and it is converted into *anthracite*, which is a nearly pure carbon.

531. *Creasote*.—The destructive distillation of wood tar, gives rise to a great variety of products, the only one of which it seems necessary to notice, is an oily, colourless, inflammable liquid called *creasote*. It has a penetrating odour of smoke, a sharp burning taste, and is chiefly remarkable for its power of depriving animal substances of their tendency to putrefaction.



SECTION II.

THE CAMPHENE SERIES.

532. *The Essential Oils*.—The essential oils which are secreted in the living plant, form, together with camphor and the resins, a very natural and closely allied group of organic products. They agree in being highly aromatic, soluble in alcohol and ether, and very sparingly, or not at all soluble in water, to which they communicate their taste and odour. They are highly inflammable, and burn with much

smoke. They do not form soaps with alkalies, and are converted into resins by the absorption of oxygen.

The essential oils may be divided into three classes; those which contain only carbon and hydrogen; those containing oxygen and destitute of acid properties; and those forming acids.

533. The oils of the first class form a very remarkable group, most of them being isomeric, and represented by the formula $C_{10}H_8$, or its multiple. These isomeric oils yield vapours having the same specific gravity 4.766. Oil of turpentine, lemon, copaiva, juniper, cubebs, pepper, and bergamotte, are the most important of this class. The constitution of oil of turpentine is $C_{20}H_{16}$; being identical with camphene; that of oil of cubebs $C_{15}H_{12}$; and that of the remainder C_8H_4 .

534. The second class contains the oils of cajeput, lavender, pennyroyal, the mints, anise, asarum, the camphor tree, &c., They consist of, or are resolved into, a solid oil called *stereoptene*, analogous to camphor, and a liquid oil; the former of which separates by long standing.

535. *Camphor*—Common camphor is a white, semi-transparent, tough, crystalline, volatile solid, of a bitter taste and peculiar odour, highly inflammable, soluble in ether and alcohol, and sparingly so in water.

Its formula is $C_{20}H_{16}O_2$, being the deutoxide of camphene. By boiling with strong nitric acid, it is converted into camphoric acid, which crystallizes in small rhomboidal tables, has a sour and bitter taste, and forms soluble salts.

536. Camphor is the *stereoptene* of the oil of the camphor tree. Various other oils yield camphor, the composition of which varies with its origin. Those of peppermint, anise, and fennel, are isomeric with their oils, those of turpentine, and asarum, are their hydrates, and those of camphor, and most others, their oxides.

When chlorohydric acid gas is passed into oil of turpentine, they combine and form a white crystalline solid, smelling strongly of camphor, which is called artificial camphor, from its resemblance to that body.

537. *The Resins*.—The resins approach closely to the camphors in constitution and properties, but differ in being decomposed before they are volatilized, and in possessing acid properties which enable them to combine with alkalies and form a species of soap. They are produced by the oxidation in the living plant itself, of essential oils isomeric with oil of turpentine. They mostly exude naturally from the living plant, in which case several distinct products are usually blended together.

538. The most important are common rosin, copal, mastich, sandarac, guaiacum, copaiva, amber, olibanum, caoutchouc, and dragon's blood. The principal use of the resins is in the preparation of varnishes.

539. *Caoutchouc*.—This is the most singular, and promises to be the most useful, of all these resins. It is a soft, tenacious, inflammable solid, remarkable for its great elasticity. It is insoluble in alcohol and water, but soluble in essential oils and in the volatile liquid obtained from its decomposition by heat in close vessels. It thus yields a varnish capable of being applied to the softest fabrics, and surpassing all other known bodies in the degree in which it combines insolubility, flexibility, elasticity, and resistance to the ordinary causes of change and decay.

540. *Benzule*.—The third class of essential oils contains the oils of bitter almonds, of cloves, of cinnamon, and of the spiræa ulmaria. The careful examination to which these oils have been subjected, has thrown much light on the laws of organic combination. The oil of bitter almonds is a feeble acid, the base of which is hydrogen, and the electro-nega-

tive element is a complex radical called benzule, of which the formula is $C_{14}H_5O_2$, and the symbol, Bz. This radical combines with the simple elements chlorine, iodine, bromine, and sulphur, forming compounds which are neither acid nor basic.

541. *Benzoic Acid*.—Its protoxide is the benzoic acid, BzO , which exists in combination with resin in what are called the Balsams, viz. gum benzoin and storax, and the balsams of Peru and Tolu.

Benzoic acid is a volatile, inflammable acid, having a fragrant odour when heated, and a sweet, aromatic taste. It is soluble in alcohol and water, and crystallizes in needles of a silky lustre. It is a monobasic acid, from which the atom of base cannot be separated, and the formula of its salts is M, BzO_2 .

542. *Oil of Bitter Almonds*.—This oil does not exist ready formed in the plant, but is evolved in the decomposition of *amygdaline*, an albuminous solid, which forms a principal portion of the kernels of the bitter almonds. When these are macerated in water and distilled, the amygdaline disappears, and oil of bitter almonds, cyanohydric and formic acids, and sugar, are formed. The oil of bitter almonds is a colourless, transparent, inflammable fluid, of a strong, peculiar odour, and burning taste, which absorbs oxygen from the air, and is converted into benzoic acid. It unites with various bases, and undergoes a series of highly interesting changes by the action of different reagents. It seems probable that the true radical in all these products is $C_{14}H_5$; of which benzule is itself the deutoxide.

553. The oil of cinnamon is the compound of a peculiar radical, cinnamule, $C_{18}H_7O_2$, with hydrogen, and, like the oil of bitter almonds, it may be regarded as a feeble acid. Cinnamule unites with an atom of oxygen to form an acid very similar to benzoic acid, and combines also with chlorine.

544. The oil of the spiræa ulmaria is similar in

constitution, being the hyduret of *salicule*, a complex radical, represented by $C_{11}H_8O$, which may be regarded as the deutoxide of benzule.

SECTION III.

THE OILY ACIDS.

545. The fixed oils, whether of vegetable or animal origin, closely resemble each other in composition. The animal oils are chiefly deposited in the cavities of the cellular tissue, and the vegetable oils in and around the seed. They cannot be volatilized without decomposition, and they all form soaps with the alkalies. By exposure to the air, one class of these oils, called the drying oils, absorb oxygen, and become converted into an elastic, tough solid, which renders them useful in painting.

The fixed oils are nearly inodorous and tasteless; their density varies from .9 to .96. Some of them, as the animal fats, palm oil, and cocoa-nut oil, are solid at common temperatures, but become fluid at a gentle heat. At 600° they begin to boil, suffering a partial decomposition, and disengaging an inflammable vapour at the same time. When heated to a red heat, in a close vessel, they are decomposed and evolve large quantities of olefiant gas. In the open air they burn with a clear and bright flame, and are converted into water and carbonic acid.

The fixed oils are insoluble in water, but may be permanently suspended in that liquid by means of mucilage or sugar. This mixture is termed an emulsion. They are in general sparingly soluble in alcohol and ether, although castor oil is soluble in all proportions in the former.

546. The fixed oils absorb oxygen gas when ex-

posed to the air, and become thick and rancid. The oil of flax-seed, hemp-seed, nut oil, and some others of the fixed oils, are called drying oils, because they are at length converted by this process into an elastic, gummy mass. It is this property which renders these oils valuable in painting, in the preparation of varnishes, and the manufacture of printer's ink. This absorption of oxygen by the drying oils is under some circumstances so abundant and rapid, and accompanied by the extrication of so much heat, as spontaneously to kindle easily inflammable substances, with which they may be mixed. Many extensive fires have been caused by carelessly spilling drying oils on lamp-black, cotton, flax, wool, or even shavings of wood.

The fixed oils combine with the alkalies and metallic oxides; their combination with the alkalies forms soap, and that with the metallic oxides, more particularly with the oxide of lead, forms the *plasters* of the pharmacopæias.

547. The experiments of Chevreul have shown that fixed oils consist of three proximate elements; two of them solid and crystalline, and the other remaining fluid at low temperatures. These principles, which closely resemble each other, are named stearine, margarine, and oleine. They consist of organic acids combined with an organic base called glycerine.

548. *Stearine*.—Stearine is obtained from mutton suet by the crystallization of the hot ethereal solution. It is crystalline like spermaceti, not greasy to the touch, soluble in ether and alcohol, and fusing at 143° . Stearine is found to be a bi-stearate of glycerine, and its formula is $C_{142}H_{141}O_{17}$, or $C_6H_7O_5 + 2C_{68}H_{66}O_5 + 2Aq$. Pure stearic acid is tasteless, and inodorous. It is soluble in alcohol but not in water, and crystallizes from its alcoholic solution in brilliant white plates, of a pearly lustre. Stearic

acid has a feeble reaction, its solution turns vegetable blues red, and it decomposes the alkaline carbonates. It melts at 158° , and congeals into a crystalline mass, which burns with a clear white flame, and is extensively manufactured as a substitute for wax and spermaceti for candles. Stearic acid is a bibasic acid, and the formula of its salts is $M_2 + C_{68}H_{66}O_7$. The alkaline stearates are the only ones soluble in water.

549. *Margarine*.—Margarine is found with stearine, though in smaller proportions in most animal and vegetable oils. It is the principal ingredient of human fat. It closely resembles stearine, but fuses at 118° , and is more soluble in ether and alcohol. *Margaric acid* crystallizes in white needles, and fuses at 140° . It is a monobasic acid, and its formula is $C_{34}H_{33}O_3 + Aq$.

550. *Oleine*.—Oleine exists in conjunction with stearine and margarine in almost all oils and fats. It is soluble in cold alcohol, and may thus be obtained separately. It remains fluid at 0° , and exists nearly pure in almond oil. It is a binoleate of glycerine, and its formula is $C_{94}H_{37}O_{15} = C_8H_7O_5 + 2C_{44}H_{39}O_4 + 2Aq$. The oleic acid is an oily liquid having a slight smell and a pungent taste. It is acid to test paper, soluble in ether and alcohol, and crystallizes in needles when cooled below 32° . The formula of oleic acid is $C_{44}H_{39}O_4 + HO$.

551. *Glycerine*.—These acids exist in nature in combination with an oxide of hydrocarbon, which has received the name of glycerine. This is separated during the process of saponification, and may be obtained in combination with an atom of water. The hydrate of glycerine is an inodorous syrupy liquid, of the sp. gr. of 1.27, and very sweet to the taste. It is insoluble in ether, but miscible in all proportions with water and alcohol. Its solution is inca-

pable of being fermented. Its formula is $C_6H_7O_8 + Aq$. Glycerine, therefore, differs from mannite in containing one atom more of oxygen.

552. The various soaps of commerce are the stearates, margarates, and oleates of potassa and soda.

The salts of soda are the hard white soaps, and those of potassa are a semi-transparent gelatinous mass. Yellow soap contains about one-third of resin to two of fat.

Almost every variety of oil and fat, contains, along with stearine, margarine, and oleine, a larger or smaller portion of a peculiar acid, which belongs to the same group as those above described, has similar reactions with the bases, and is combined in a state of nature with glycerine.

SECTION IV.

NATIVE ORGANIC ACIDS.

553. It would swell an elementary treatise beyond its proper size, to attempt to treat of the great variety of native acids which have been discovered, and their bare enumeration would be useless. All that can be done, is to point out the properties of the most important.

554. The views which have been unfolded respecting the nature of active acids, and of salts, are placed in still clearer light by the constitution of the organic acids. All these acids are what is called *hydrated*, that is, exist in combination with one or more atoms of water, which are essential elements of their constitution. The number of basic atoms in the salts which they form, is always determined by the atoms of this basic water, and the hydrated acid may be regarded as a salt of hydrogen. These views

are further strengthened by the changes which take place in tartaric acid, which is the only organic acid from which we are able to expel all the water. In its anhydrous state, it is destitute of acid properties, and is insoluble in water.

555. *Pyrogenous Acids*.—When these acids are submitted to the action of strong heat in a close vessel, they give rise in most cases to new acids, which are called, from the circumstances in which they are formed, the pyrogenous acids. Thus, citric acid, $C_{12}H_8O_{11} + 3Aq$, when heated, is converted into pyrocitric acid, $C_6HO_4 + HO$, which is identical with the aconitic acid, that exists in the aconitum napellus, or wolf's bane.

556. *Tartaric Acid*. \bar{T} .—This acid exists naturally in combination with lime or potassa, in the juices of several fruits. It is found in the grape in the form of bitartrate of potassa, and as this salt is less soluble in alcohol than in water, it is deposited during the fermentation of the juice of the grape, and has long been known in commerce by the name of crude tartar, or when purified and pulverized, by the name of cream of tartar. Tartaric acid has strong acid properties; it is very soluble in water, crystallizes in rhomboidal prisms, which are permanent in the air, and may be distinguished from all other acids by forming white granular crystals, when added to a solution of potassa or any of its salts. The formula of tartaric acid is $C_4H_4O_{10} + 2HO$. It is a bibasic acid, and the constitution of its salts is $C_4H_4O_{10} + M, H$, or $2M$.

The bitartrate of potassa, $KO, HO + \bar{T}$, the common cream of tartar of the shops, is a natural secretion of the grape, and being insoluble in alcohol, it is precipitated during the fermentation of the juice. It is sparingly soluble in water. The basic tartrate, $2KO + \bar{T}$, is the soluble tartar of the shops. Rochelle

salt is the double tartrate of potassa and soda, KO , $\text{NaO} + \overline{\text{T}}$.

557. Tartar emetic is the tartrate of potassa and antimony, KO , $\text{St}_2\text{O}_3 + \overline{\text{T}} + 2\text{Aq}$; this water is driven off at 212° , and when the salt is heated to 480° , two additional atoms of water are formed, which must arise from the disintegration of the salt, as they are restored when it is again dissolved. The real constitution of tartar emetic is not understood; and is difficult to reconcile with the binary theory of salts, which supposes the active acid to be a salt of hydrogen, and that the ordinary salts are formed by the union of the oxygen of the base with this hydrogen. To explain the constitution of tartar emetic on this theory we must suppose tartaric acid to be quadribasic and not bibasic, as is the fact. The *boracic acid* unites as a base with the bitartrate of potassa to form a double salt, which presents the same theoretical difficulties as tartar emetic.

558. Tartaric acid is changed by fusion into an isomeric acid called the *tartralic*, of which the atomic number is one and a half times that of tartaric acid. By longer fusion it loses all its water and is converted into a porous white mass, insoluble in water and alcohol, and destitute of acid properties. When distilled at still higher temperatures, it is converted into a monobasic acid—the pyrotartaric, of which the constitution is $\text{C}_4\text{H}_3\text{O}_3$.

559. *Racemic Acid*.—The wines of the Vosges mountains in France, deposit during certain seasons, a peculiar salt of potassa, the acid of which is not the tartaric, but an isomeric acid, the *racemic*. It is less soluble than the tartaric acid, and its salts differ in crystalline form from the tartrates. It forms a parallel series of salts with the tartaric acid, and has the same combining number, although it is said by Fresenius to be a monobasic, and not a bibasic acid.

560. *Citric Acid.* $\overline{\text{Ci}}$. This acid exists in the juices of the lemon, the gooseberry, and other fruits. It has an agreeable sour taste, is soluble in less than its weight of cold water, and usually crystallizes in large rhombic prisms, containing two atoms of water of crystallization. It is a *tribasic* acid; its formula being $\text{C}_{12}\text{H}_5\text{O}_{11} + 3\text{HO}$; and that of its salts, $\text{C}_{12}\text{H}_5\text{O}_{14} + \text{M}_3$, M_3H , or MH_3 . Citrate of soda consists of $\text{C}_{12}\text{H}_5\text{O}_{14}$, $\text{Na}_3 + 4\text{Aq} + 7\text{Aq}$. At 212° the seven atoms of water are driven off, and the remaining four are not parted with, till the heat is raised to 400° .

The pyrocitric acid has already been noticed.

561. *Malic Acid.*—This acid exists along with citric acid, in the berries of the mountain ash and other fruits. It is strongly acid and deliquescent. It is a *bibasic* acid, its constitution being $\text{C}_8\text{H}_4\text{O}_8 + 2\text{HO}$, and that of its salts, $\text{C}_8\text{H}_4\text{O}_{10} + \text{M}_2$, or MH . When heated it gives out two atoms of water, and is converted into two acids, one of which, the *Maleic*, is a *bibasic* acid, isomeric with the aconitic, and having double its atomic number, viz. $\text{C}_8\text{H}_2\text{O}_6 + 2\text{HO}$. The other is a *monobasic* acid, of which the formula is $\text{C}_4\text{HO}_3 + \text{HO}$. It is identical with the fumaric acid which exists naturally in the fumitory, and in Iceland moss.

562. *Tannic Acid*—This acid principle is the chief cause of the astringency of vegetable substances. It exists abundantly in the inner bark of the oak, in gall nuts, in the inspissated juices, kino and catechu, and in the seeds of the grape. Pure tannic acid is prepared by submitting finely powdered gall nuts to the action of cold ether. The water contained in ether combines with the tannic acid, while the remaining proximate principles of the gall nuts are dissolved by the ether. The aqueous solution, which forms a dense stratum at the bottom of the vessel, is separated and carefully evaporated to dryness. Pure tannic acid is colourless and

inodorous, has a purely astringent taste without bitterness, and may be preserved dry without change. It is very soluble in water, and the solution reddens litmus paper, and decomposes the alkaline carbonates. Tannic acid forms a salt of a deep blue colour with the peroxide of iron, and combines with many other of the metallic oxides.

Tannic acid is distinguished from all other substances by forming with gelatine a compound which is insoluble in water. This compound, which is called leather, is formed whenever the skins of animals, which consist chiefly of gelatine, are exposed to the continued action of a solution of tannic acid. Leather, when dried, becomes tough and hard, and resists putrefaction.

The salts of tannic acid are remarkable for their peculiarities of colour; and it is on this account highly useful as a test. It is a tribasic acid, its formula being $C_{12}H_8O_9 + 3HO$.

563. *Gallic Acid*.—This acid is obtained by boiling for a few minutes an infusion of gall nuts with a strong solution of potassa, and adding an excess of sulphuric acid, which causes a copious precipitate of gallic acid. This acid is bibasic, and its formula is $C_7H_5O_6 + 2HO$. It is also formed by the decomposition of a solution of tannic acid, which absorbs from the air 8 atoms of oxygen, and forms $4 \overline{CO_2}$, $2C_7H_5O_6$, $2HO$, and HO . Three atoms of tannic acid contain the elements of six atoms of gallic acid, and one atom of grape sugar.

564. Pure gallic acid has a weak acid and astringent taste, and reddens litmus paper. It is freely soluble in boiling water, but requires 100 parts of cold water to dissolve it. The pergallate of iron is a salt of a deep blue colour; common writing ink is a mixed solution of the pertannate and pergallate of iron. Gallic acid does not precipitate solutions of

gelatine, as does the tannic acid. When anhydrous gallic acid is exposed to a heat of 419° , it is decomposed into one atom of carbonic acid, and one of *pyrogallic acid*, consisting of $C_6H_3O_3$. This acid sublimes and condenses into brilliant, white, scaly crystals. It is more soluble than gallic acid, and strikes a blackish blue colour with the persalts of iron. When pyrogallic acid is heated to 480° , it is decomposed; two atoms yielding three atoms of water, and one atom of *metagallic acid*, $C_{12}H_3O_3$. Metagallic acid is a black, shining, insoluble mass, that is dissolved by the alkalies, and forms neutral salts, most of which are black and insoluble. During the process for the preparation of gallic acid, another modification of that acid subsides in the form of an insoluble gray powder. It has been called *ellagic acid*, and consists of $C_7HO_3 + HO$, containing one atom less of water than the gallic acid.

565. *Pectic Acid*.—When the filtered juice of certain plants, such as the carrot or the beet, is mixed with alcohol, a gelatinous mass subsides, which may be collected on a filter, washed, and dried. It then forms a transparent, insipid mass, one part of which forms a firm jelly with one hundred parts of water. This vegetable jelly is called *pectine*. By long boiling it changes into *pectic acid*; which exists in plants as a pectate of lime, and may be obtained from their juice by the action of chlorohydric acid. Pectic acid is obtained in white transparent scales, acid to the taste, and reddening litmus paper. Its solution does not gelatinize, but is converted into a firm jelly by acids, lime water, and sugar. It is a bibasic acid, isomeric with pectine, and its formula is $C_{32}H_{17}O_{22} + 2HO$.

CHAPTER IV.

NITROGENOUS COMPOUNDS OF CARBON AND HYDROGEN.

SECTION I.

IMMEDIATE ORGANIC PRODUCTS.

566. The principal distinction between animal and vegetable products, is the presence in the one case, and the absence in the other, of nitrogen. Many animal secretions, however, such as the fatty oils, are destitute of nitrogen, and many vegetable products, such as gluten, and the organic alkalies, contain it. The presence of nitrogen renders the substances more liable to putrefaction, and greatly complicates the results of decomposition.

567. Fibrine, albumen and caseine, are to animals, what lignine, gum, starch, and sugar, are to vegetables; their most copious and important secretions, products essential to the life and health of the individual.

568. *Fibrine*.—Fibrine constitutes the basis of the flesh of animals, and is deposited in the muscular tissue from the blood, of which it forms a principal constituent, and in which it remains during life in a liquid state. It may be obtained by stirring freshly drawn blood with a bundle of twigs, to which the fibrine adheres in soft tenacious masses; and it is purified by washing in water, and digesting in alcohol and ether. When dried at a gentle heat, it is a yellowish, opaque, tasteless, insoluble mass, which undergoes no change when kept in dry air. In the damp it absorbs so much water as to treble its weight, and become soft, elastic, and flexible. When long boiled in water it is decomposed and dissolved.

569. Fibrine absorbs cold oil of vitriol, and forms

with it a neutral compound soluble in water. It is dissolved in acetic acid, and by caustic potassa; and when exposed to the damp speedily undergoes putrefaction.

570. *Gluten*.—When the newly expressed juices of vegetables are allowed to stand, a green gelatinous precipitate is formed, which becomes by the removal of the colouring matter, a grayish white substance, having all the properties of fibrine. This fibrine is contained in large quantities in the juice of grapes, and in the seeds of the cerealia. The gray, viscid, fibrous, elastic mass, which remains after the starch has been separated from wheat flour, is nearly pure fibrine, and bears the name of Gluten. Boiling alcohol separates it from the albumen with which it is mixed, and the pure gluten may be precipitated from the solution by water. Pure gluten is insoluble in water and ether, but forms a thick syrupy solution in alcohol, and dissolves in acetic acid, and alkaline solutions. When dry it is a hard, brittle mass of a yellow colour, which undergoes no change in dry air, but absorbs moisture in the damp, swells, becomes a soft, adhesive, elastic mass, which soon ferments and undergoes putrefaction.

571. *Albumen*.—This substance is diffused throughout the whole animal frame, and exists in two conditions, a soluble, and an insoluble one. Soluble albumen is in its purest form in the white of eggs, in which it is united with water, carbonate of soda, and saline matter. Liquid albumen is a thick, glairy fluid; insipid, inodorous, easily miscible with water, and perfectly soluble in a large quantity of that fluid. When dried at a low temperature, it becomes a solid, transparent mass, which retains its solubility. At 160° , albumen is coagulated, as it is also by alcohol, and the stronger acids. Dr. Turner supposes that liquid albumen is a solution of albumen in water, formed at the moment of being secreted, but that the

union is so feeble as to be broken by slight causes, which render the albumen quite insoluble, without effecting any change in its composition. The solubility of nascent silica, and its insolubility under all other circumstances, furnish an analogous case. Water diluted with $\frac{1}{1000}$ of its weight of albumen, is rendered opaque by boiling. Solutions of albumen coagulate at 212° , and are much used for clarifying turbid solutions; for the coagulated albumen carries with it, to the surface, the foreign particles which render the liquid turbid. Albumen is precipitated by several of the metallic salts, and is a useful test of the presence of corrosive sublimate, with which it forms an insoluble, inert precipitate. It is, therefore, an effectual antidote to the effects of that poison. So delicate a test is this chloride of the presence of albumen, that it will occasion a milkiness in water containing only $\frac{1}{30000}$ part of albumen. The precipitate is said to be a combination of oxide of mercury and albumen. Albumen may also be obtained from the liquid, which has been used in the separation of fecula from wheat flour. If the water, from which the starch has been deposited, be heated, it will become more or less cloudy, and white films separate, which have all the properties of coagulated albumen. It exists in plants in only small quantities; the seeds of the cerealia contain from $\frac{1}{10}$ th to $3\frac{1}{4}$ per cent, the leaves of the cabbage, the stalks of asparagus, and the roots of turnips, yield it in larger quantities. The albumen from vegetables is destitute of elasticity when softened, and dries into a hard, white mass. It is soluble in water; its solution is coagulated by heat, and it has all the properties of animal albumen.

572. *Caseine*.—This element is the principal substance of the curd of cheese, from which it may be obtained by digestion in water, and in alcohol, which dissolve out the foreign substances, with which it is

mixed. Caseine dries into a semi-transparent, yellow mass, and is perfectly insoluble both in cold and hot water; although soluble in water to which acetic acid, or an alkali, has been added. It is unalterable in a dry atmosphere, and the changes which old cheese undergoes, are due to the foreign substances mixed with the caseine. Caseine also exists in the seeds of leguminous plants.

573. Fibrine, albumen, and caseine, like starch, gum, and sugar, closely resemble each other, and may be converted one into the other. By digestion at 80° in a solution of nitre, fibrine acquires the properties of liquid albumen; and caustic potassa throws down liquid albumen in the form, and with the properties of caseine. In the living organism, these principles are all liquid: the fibrine coagulates by mere exposure to the air, the albumen by heat, and the caseine by the addition of rennet, or an acid.

When these substances are dissolved in a solution of caustic potassa, and then exposed for some time to a high temperature, the addition of acetic acid, causes all the organic matter to fall in a gelatinous, translucent precipitate, of exactly the same character in all cases.

574. *Proteine*.—This substance, to which the name of proteine (the first element) has been given, is common to all these compounds, and the ultimate analysis of proteine, albumen, fibrine, and caseine, gives absolutely the same proportions of carbon, hydrogen, nitrogen, and oxygen, with small and varying quantities of sulphur and phosphorus. The formula, which, according to Liebig, best represents the composition of proteine (Pr) is, $C_{48}N_6H_{36}O_{14}$. Caseine differs from proteine in containing a minute quantity of sulphur; albumen and fibrine differ from it in containing sulphur and phosphorus; and their composition will be represented thus; caseine, $Pr+S$; albumen, $Pr+P+S$; and fibrine, $Pr+P+2S$. The quan-

tities of sulphur, and phosphorus in the above formulæ do not represent equivalents; for were they so framed as to do this, the formulæ would thus stand; caseine, $\text{Pr}_{20} (\text{C}_{960}\text{N}_{120}\text{H}_{720}\text{O}_{280}) + \text{S}$; albumen, $\text{Pr}_{20} + \text{P} + \text{S}$; and fibrine, $\text{Pr}_{20} + \text{P} + \text{S}_2$. These numbers startle us by their magnitude, for they make an atom of fibrine to contain 2083 elemental atoms: and it is much safer in the present state of our knowledge, to take the simple statement of Liebig, as a sufficiently close representation of facts.

575. *Gelatine*.—Gelatine exists abundantly in many of the solid parts of animals, such as the skin, bones, and cartilages. It does not appear to exist in any of the animal fluids. It is distinguished from all other animal principles by its ready solubility in boiling water, and by the bulky, semi-transparent jelly, which the solution forms on cooling. One part of gelatine, dissolved in 100 parts of water, becomes solid on cooling. Isinglass, which is the dried air-bladder of the sturgeon, is the purest form of gelatine; common glue is gelatine prepared from the skins and hoofs of animals. Gelatine is soluble in most of the diluted acids, and in alkaline solutions; concentrated sulphuric acid dissolves it without charring, and converts it into a peculiar saccharine principle, which is soluble in water, and in alcohol, and crystallizes in large prisms, which consist of $\text{C}_{16}\text{H}_{15}\text{N}_4\text{O}_{11} + 3\text{Aq}$. The composition of gelatine itself is calculated by Liebig, from Mulder's analysis, to be, $\text{C}_{54}\text{N}_9\text{H}_{42}\text{O}_{20}$.

If a solution of common salt, and one of alum, be poured into a solution of gelatine, the latter falls down in combination with alumina. On this principle is founded the manufacture of white leather, by the process called tawing.

576. *Bones*.—Gelatine constitutes about one third of the solid material of bone, and may be separated from the earthy skeleton which envelopes it, by long

digestion in boiling water. The earthy skeleton consists, in different animals, of from 80 to 95 per cent. of phosphate of lime, from 2 to 20 per cent. of carbonate of lime, a small portion of carbonate of soda and magnesia, and a trace of fluoride of calcium. The phosphate of lime yields by analysis, 8 atoms of lime, and 3 of phosphoric acid. The acid is the tri-basic acid, and Graham supposes the bone phosphate to be a combination of two phosphates; viz: $2(3\text{Ca O, P}_2\text{O}_5 + \text{Aq}) + (\text{HO, 2Ca O, P}_2\text{O}_5 + \text{Aq})$.

SECTION II.

CYANOGEN.

577. When any of the foregoing animal matters are calcined with potash, there is obtained by lixiviation and evaporation, a yellow crystalline salt, which has long been known as yielding with sulphate of iron, the beautiful pigment, prussian blue. When this prussian blue is boiled with half its weight of red oxide of mercury in four parts of water, the clear solution yields by evaporation, colourless, prismatic crystals. These crystals are a combination of mercury, with the substance which was combined with potassa and iron, in the prussian blue.

578. By heating the crystals in a glass flask containing no lead, the mercury is volatilized, and a gas escapes which may be collected over mercury. It is colourless, of a peculiar odour, and irritates the eyes. Its sp. gr. is 1.816; it extinguishes burning bodies, but is itself inflammable, and burns with a beautiful purple flame. When 100 measures of this gas are mixed with 200 measures of oxygen, and exploded, the products are 200 measures of carbonic acid, and 100 of nitrogen. The former contains 200

measures of vapour of carbon, so that the gas consists of 200 vapour of carbon, and 100 nitrogen, condensed into 100 measures. It is therefore a bi-carburet of nitrogen, and its formula is $N C_2=26.39$.

579. From its close affinity to the simple elements, and the multitude of its combinations, it has received a simple elemental name, and is called cyanogen from *κυανος*, blue, and *γενναω*, I generate, and its symbol is Cy. Beneath the pressure of four atmospheres, cyanogen becomes a limpid fluid. It supports a strong heat without decomposition. At 60° , water absorbs 4.5 times, and alcohol 23 times its volume.

580. *Paracyanogen*.—When the bicyanide of mercury is decomposed by heat, a brown carbonaceous mass is left in the retort, which is found to have the same composition as cyanogen, but which yields very different products by the action of the same reagents. This solid carburet of nitrogen, which is isomeric with cyanogen, has received the name of paracyanogen, and its formula is N_4C_8 .

581. Cyanogen belongs to the class of salt radicals; it forms true haloid salts with the metals, and although it cannot be made to unite directly with oxygen, it can be indirectly combined with it, and forms a very remarkable group of isomeric acids.

582. *Cyanic Acid*.— $CyO=34.39$. Cyanic acid is obtained in combination with an atom of water, and is liquid, with a penetrating, pungent odour, like that of strong acetic acid; it excoriates and blisters the skin, is very volatile, and has strong acid properties.

Cyanic acid is remarkable for the facility with which its solution is converted into carbonic acid and ammonia. One atom of the acid combines with three atoms of water, and is resolved into two atoms of carbonic acid, and one of ammonia.

Cyanic acid is a monobasic acid, and forms crystalline salts of considerable permanency.

583. *Fulminic Acid*.— $\text{Cy}_2\text{O}_2 + 2\text{HO} = 68.78$. This acid has never been insulated, and is known only in combination. It is a bibasic acid, and forms salts remarkable for the instability of their constitution. The most remarkable of these are the fulminates of silver and mercury. The former is prepared by dissolving silver in 10 parts of nitric acid, sp. gr. 1.35, and pouring the cold solution into 20 parts of alcohol. The mixture is made to boil gently, and is then slowly cooled, when it deposits the fulminate of silver in snow white, silky crystals. The formula of this salt is $\text{Cy}_2\text{O}_2 + 2\text{AgO}$. It detonates violently by the slightest friction, and by contact with sulphuric acid. The fulminate of mercury is prepared from a solution of mercury in nitric acid, in the manner above described. Its formula is $\text{Cy}_2\text{O}_2 + 2\text{HgO}$. It explodes by a smart blow, and is the salt used in the percussion guns. The paste with which the percussion caps are filled, is prepared by finely tritulating 10 parts of the salt, with 30 of water, and then thoroughly mixing the soft mass with six parts of nitre.

584. *Cyanuric Acid*.— $\text{Cy}_3\text{O}_3 + 3\text{HO} = 103.17$. This acid is obtained by dissolving the solid chloride of cyanogen in water. It is colourless, inodorous, and sparingly soluble in water. It feebly reddens litmus paper, and crystallizes in rhombic prisms, which contain 4 equivalents of water of crystallization permanently. It is a tribasic acid and forms soluble salts. The cyanurate of silver, $3\text{AgO} + \text{Cy}_3\text{O}_3$, may be heated to 600° without decomposition.

585. When dry cyanuric acid is heated to low redness in a retort, it is decomposed into hydrated cyanic acid, which distils over, and may be collected in a receiver surrounded by a freezing mixture. As soon as the vessel has acquired the common temperature, a violent molecular agitation, accompanied with a great rise of temperature, takes place, and the

liquid is transformed into a white, porcelanous mass, which is insoluble in water, alcohol, and ether, and which is reconverted into hydrated cyanic acid by again exposing it to great heat.

586. The apparent isomerism of the oxygen acids of cyanogen, is very satisfactorily explained by the new views of the constitution of salts and acids. According to these views the formula of the cyanates is $M + CyO_2$; that of the fulminates, $2M$, or $M, H + Cy_2O_4$; and that of the cyanurates, $3M, M_2H$, or $MH_2 + Cy_3O_6$.

587. *Cyanohydric Acid.—Hydrocyanic Acid.—Prussic Acid.—Cyanide of Hydrogen.*— $CyH = 27.39$. This acid may be formed by the direct union of its elements; it is found native in combination with the oil of bitter almonds, and in the water distilled from the leaves of peaches, the wild cherry, and the cherry laurel. It is also formed by passing the formiate of ammonia, $(NH_4O + C_2HO_3)$ through a red hot porcelain tube, by which it is converted into this acid, (C_2NH) and water, $(4HO)$. The anhydrous acid is a clear, limpid, inflammable fluid of the sp. gr. of .697. It boils at 80° , and congeals at 5° . It has a penetrating, bitter taste, a very peculiar odour, and mixes freely with water, alcohol, and ether. It is a most powerful poison, and is rapidly decomposed by exposure to light.

588. *Metallic Cyanides.*—Cyanogen forms a series of true haloid salts with the metals, and so energetic is its affinity for some of them, that it will take palladium from all its other compounds, and that potassium, when heated in it, takes fire, combining with, but not decomposing the cyanogen.

The cyanide of potassium is fusible and soluble, crystallizes in cubes, has a pungent, alkaline taste, and is highly poisonous.

The bichyanide of mercury crystallizes in quadrangular prisms, is colourless, inodorous, soluble in

water, has a disagreeable metallic taste, and is highly poisonous. When heated it is resolved into mercury and cyanogen.

589. With sulphur, iron, and cobalt, cyanogen forms compounds which are, like itself, genuine salt radicals, and which form with hydrogen, acids, which are decomposed by metallic oxides, in the same manner as chlorohydric acid, thus forming genuine salts.

590. *Ferrocyanogen*.—With iron, cyanogen forms two compounds; the constitution of the first, called ferrocyanogen, is FeCy_3 ; its symbol is Cfy , and its equivalent 107.17. It forms with hydrogen a bibasic acid, the *ferrocyanohydric acid*, of which the formula is $\text{FeCy}_3 + \text{H}_2$. The acid is a white, crystalline mass, the salts of which were originally called prussiates. Thus the yellow prussiate of potassa, is the basic ferrocyanide of potassium, the formula of which is K_2Cfy . It is the yellow salt, prepared by calcining animal matters with potash, and is obtained in large, flat, quadrangular crystals, which contain 3 atoms of water. It is of a lemon yellow colour, and a slightly bitter taste. It forms double salts with the other ferrocyanides, and is much used as a test for iron.

591. *Ferridcyanogen*.—The second compound of iron and cyanogen, is called ferridcyanogen; it is isomeric with the former, and its formula is Fe_2Cy_6 ; its symbol, Cfdy , and its equivalent, 214.34. It unites with three atoms of hydrogen to form a tribasic acid, the *ferridcyanohydric acid*. The ferridcyanide of potassium is the salt, known by the name of the red prussiate of potassa, and is formed by passing chlorine through a solution of yellow prussiate of potassa, till it ceases to give a precipitate of prussian blue, with persulphate of iron. It crystallizes in crystals of a deep red colour, and is valuable as a test for the metals.

592. *Prussian Blue*.—There are several com-

pounds of cyanogen and iron, prepared under the name of prussian blue. The common prussian blue is prepared by mixing together solutions of yellow prussiate of potash, and sesquisulphate of iron. It contains $\text{Cy}_3\text{Fe}_7 + \text{Aq}$, and consists of one atom of ferridcyanide of iron, $\text{Fe}_3 + \text{Fe}_2\text{Cy}_6$, combined with one of the acid ferrocyanide of iron, $\text{FeH} + \text{FeCy}_3$.

A prussian blue, celebrated under the name of Turnbull's blue, is prepared from the red prussiate of potassa; it yields Cy_6Fe_5 , and is the basic ferridcyanide of iron, $\text{Fe}_3 + \text{Fe}_2\text{Cy}_6$.

Prussian blue is insipid, insoluble, and inodorous, of an intensely pure, and beautiful blue colour. It loses its colour in the direct light of the sun, but recovers it in the dark.

593. The cyanide of cobalt, *cobaltocyanogen*, Co_2Cy_6 , and the bisulphuret of cyanogen—*sulphocyanogen*, CyS_2 , are compound radicals, resembling ferrocyanogen, which form acids with hydrogen, and salts with the metals.

The compounds of cyanogen with the salt radicals, resemble those of these elements with each other.

594. *Mellon*.—Sulphocyanogen is decomposed by heat into sulphur, sulphocarbonic acid, and an insoluble yellow powder, the constitution of which is C_6N_4 . This carburet of nitrogen has received the name of *mellon*. It forms an acid with hydrogen, and haloid salts, and yields by the action of reagents, various singular and complicated products, the constitution, and relations of which, are imperfectly understood.



SECTION III.

AMIDE.

595. Almost the only product of organic decomposition which is destitute of carbon, is ammonia.

In order to explain the changes which this substance undergoes, the existence of a hypothetical radical, called *amide*, of which the formula is NH_2 , has been assumed.

596. *Ammonia*.—Ammonia is a constant and copious product of the putrefaction of organic bodies containing nitrogen. A salt known, and highly prized, from remote ages, received its name of sal ammoniac from the temple of Jupiter Ammon, near which it was found as a natural product. When this salt is mixed with caustic lime in a state of fine powder, and subjected to heat, a gas of a very pungent and penetrating odour, which powerfully irritates the eyes and nostrils, is evolved. The same gas is produced during the destructive distillation of animal matters, especially of bones, and being frequently obtained from the horns of the deer, its solution in water was long known by the name of *spirits of hartshorn*. It is an invisible gas which is liquefied beneath a pressure of $6\frac{1}{2}$ atmospheres; its sp. gr. is .5898. It extinguishes burning bodies; the flame of a taper before going out is somewhat enlarged, and assumes a yellow colour; and a small jet of the gas burns in oxygen gas.

597. Ammoniacal gas, according to Kane, has no action on vegetable colours, when perfectly dry, but if damp, it is powerfully alkaline. It has a strong affinity for water, which absorbs 780 times its volume. The sp. gr. of a solution containing 690 times its volume is .875. The concentrated solution is prepared by decomposing chlorohydrate of ammonia by means of lime, and passing the disengaged gas through water, kept cool by surrounding the vessel with ice or wet cloths. Owing to its strong affinity for water, ammonia must always be collected over mercury. A piece of ice introduced into a vessel of this gas is instantly liquefied, and the gas is instantly absorbed. Ammonia has all the proper-

ties of an alkali; it has an acrid taste, stains turmeric paper of a brown colour, and is a powerful base, neutralizing the strongest acids.

598. When a succession of electric sparks is passed through this gas, it is entirely decomposed; its volume is doubled, and the resulting gases are three volumes of hydrogen, and one of nitrogen; its formula may therefore be given as NH_3 , and its equivalent, as 17.15.

599. A weak solution of ammonia is decomposed by the secondary action of the voltaic pile; hydrogen, from the decomposed water, being evolved at the negative, and nitrogen at the positive electrode. But if a portion of mercury form the negative electrode, no hydrogen is evolved, and the mercury is rapidly converted into a light porous substance, having the lustre and all the characters of an amalgam. So unstable however is its constitution that if the current of electricity ceases, it is at once resolved into mercury, two volumes of ammoniacal gas, and one volume of hydrogen. This decomposition is retarded by subjecting the amalgam to an intense cold before discontinuing the current. It may be preserved at zero, and is then found to crystallize in cubes, and to retain its metallic character. (Kane.)

600. *Ammonium*.—This amalgam must be regarded as a compound of mercury, and of these gases, in the above proportions; and as the metals do not form compounds possessing metallic properties, with any other bodies than metals, the existence of a compound metal which has not yet been insulated, and which must be represented by NH_4 , is inferred. To this supposititious metal, Berzelius gives the name of *ammonium*. He supposes the volatile alkali to be the protoxide of ammonium, $\text{NH}_4 + \text{O}$, which is resolved by decomposition into one atom of water, one of nitrogen, and three of hydrogen. This the-

ory places ammonia in the class of metallic protoxides, to which the other alkalies, potassa, soda, and lithia, belong, and is supported by many strong analogies.

601. If this view be correct, it is evident that the protoxide of ammonium is the hydrate of ammonia; such is in fact the constitution of the salts of ammonia with the oxygen acids, of which an atom of water is an essential element.

The real nature of ammonia is a question of much interest and difficulty, and there are other facts which seem to favour a theory that connects it with the series of organic radicals above described.

602. *Amide*.—When the oxalate of ammonia, ($C_2O_3 + NH_4O$) is heated, two atoms of water are disengaged, and a new substance, called *oxamide*, of which the formula is $C_2O_2 + NH_2$, is evolved. So, likewise, chloride of mercury, ($HgCl$), and ammonia, (NH_3), produce chlorohydric acid, (HCl), and Hg, NH_2 . One atom of bichloride of platinum, and two of ammonia, produce $2HCl$, and $Pl + 2NH_2$. It is evident, therefore, that the third atom of hydrogen is not so closely united to the nitrogen, as the remaining two; for the former is separated by the ordinary chemical reactions, but the latter are not disengaged till the ammonia is resolved into its ultimate elements. It is hence concluded, that the real base of ammonia is this bihydroguret of nitrogen, which has received the name of amide, and of which the formula is NH_2 , the symbol, *Ad*, and the number, 16.15.

603. Although amide has not been insulated, it forms compounds with many of the metals and organic radicals. When potassium is heated in dry ammoniacal gas, an atom of water is disengaged, and a fusible olive green solid remains, which is K, NH_2 , the amidide of potassium. The amidide

of mercury forms compounds with the mercurial chlorides, oxides, and salts, some of which have been long known and used in the practice of medicine. The white precipitate of the shops is the chloride and amidide of mercury; $\text{HgAd} + \text{HgCl}$.

604. Amide combines with many of the organic radicals: its combination with benzule is called benzamide, and with carbonic oxide, oxamide. These compounds differ, in their ultimate analysis, from the benzoate and oxalate of ammonia, in yielding one atom less of water; but they are entirely destitute of saline properties, and are formed by the same change which chlorohydric acid undergoes, when it acts upon a metallic oxide; that is to say, the ammonia parts with its third atom of hydrogen, and benzoic and oxalic acids, with that atom of oxygen which constitutes them acids, thus forming one atom of the new compound, and one of water.

Oxamide is a tasteless, inodorous, snow-white crystalline powder, almost insoluble in cold water, ether, and alcohol, and readily converted into oxalate of ammonia by acids or alkalies, and by heat.

605. *Double nature of Ammonia.*—The phenomena which ammonia presents, are in one respect of a very remarkable, and of what may be called a dimorphous character. When it combines with oxygen acids, its salts, as has been stated, contain an atom of water as an essential element, and are isomorphous with the corresponding salts of potassium; and it exhibits in this respect all the properties of a highly basic metallic protoxide, as strongly as any of the class; and we are led to infer, that in these cases it is the hydrated protoxide of ammonium which enters into combination.

606. On the other hand, ammonia exhibits properties which bring it into close affinity with water, and which remove it entirely from the class of alkalies, with which, in other respects, it is so closely connected.

Many of the metallic salts copiously absorb dry ammoniacal gas, and form definite compounds, in which ammonia appears to act the part of basic water, or water of crystallization. Thus dry sulphate of zinc is converted into a bulky white powder, perfectly soluble in water, and consisting of $2 (\text{ZnO}, \text{SO}_3) + 5\text{AdH}$. The sulphates of copper, of nickel, of cobalt, and of cadmium, combine with two and a half or three equivalents of ammonia, and form soluble compounds. From some of these the ammonia escapes by mere exposure to the air; in some the salt may be sublimed without change, while in others one portion of the ammonia is more strongly retained than the rest. In these cases, it seems probable that ammonia acts as the amidide of hydrogen, analogous to the protoxide of hydrogen, and not as the protoxide of ammonium.

607. This double nature of ammonia is shown by the decomposition which takes place, when an excess of ammonia is added to a strong, hot solution of nitrate of copper. The ammoniacal nitrate of copper crystallizes in fine, purple, rhombic octohedrons. This salt deflagrates violently when heated to the melting point, and appears to consist of nitrate of ammonia, NH_4, NO_6 , and of the amidide of copper, Cu Ad ; one portion of the ammonia being resolved into amide, and the other into ammonium.

608. *Salts of Ammonium.*—Of the oxygen salts of ammonia, the nitrate is principally used for the preparation of protoxide of nitrogen. The sulphate is obtained from the liquid products of the distillation of coal, in making coal gas—and is used for the preparation of the chloride of ammonium—the crude sal ammoniac of commerce.

The phosphate of ammonia and magnesia is much used as a flux in blow pipe experiments, and was formerly called microcosmic salt.

The oxalate of ammonia is much used as a test of the presence of lime.

With carbonic acid, ammonia forms a neutral anhydrous carbonate, NH_4CO_2 , and a bicarbonate. The constitution of the latter is $\text{NH}_4\text{O}, \text{CO}_2 + \text{HO}, \text{CO}_2$. By the union of these in various proportions, several complex varieties of the carbonate are formed.

609. *Amide and the Salt Radicals*.—When ammonia is made to act on the salt radicals, and on some of the metallic oxides, certain compounds are formed of so unstable a constitution, that the slightest molecular agitation is sufficient to decompose them, with violent detonation. The extreme danger of examining and handling these preparations, has prevented their accurate analysis, but from the similarity of their properties, it is probable that the ammonia used in their preparation, undergoes the same change in all, and exists in the condition of amide, feebly combined with a salt radical, or a metallic oxide.

As traces of sal ammoniac are perceived when it is decomposed, it must contain hydrogen; and it is highly probable that it is a chloride of amide.

610. *Terchloride of Nitrogen*.—This compound is prepared by exposing a solution containing a 16th part of chlorohydrate of ammonia, to the action of chlorine gas. Minute yellow globules of the chloride soon begin to collect at the bottom. It is one of the most explosive compounds known. Its sp. gr. is 1.653. It does not congeal at zero of Fahrenheit; it may be distilled at 160° , and explodes with great violence at 212° , as well as by the mere contact of combustible substances.

With iodine and bromine, ammonia forms similar compounds; that with iodine is a brown powder, which explodes under water by friction.

611. *Fulminating Compounds with the Metals*. When the fresh prepared oxides of silver, gold, platinum, mercury, and copper, are digested in water of ammonia, an insoluble powder is formed, which

detonates with friction; and in the case of silver, and gold, with extreme violence. The composition of these bodies is uncertain. They yield hydrogen and nitrogen in the proportions to form ammonia, but it is evident that so stable a compound as ammonia, cannot, *as such*, enter into their composition.

SECTION IV.

THE ORGANIC ALKALIES.

612. The researches in organic chemistry have brought to light a multitude of proximate principles, which are secreted during the life of the plant or animal, and which are, in most cases, peculiar to the species or genus in which they exist. The most remarkable of these proximate principles is a series of organic alkalies, to which the plants that contain them owe their active medicinal properties. They all contain nitrogen, and all act as bases, neutralizing the strongest acids, and forming with them neutral crystalline salts; retaining the peculiar power over the animal system which the base itself possesses. The most remarkable of these alkalies are those found in the cinchonas, in the poppy, and the nux vomica. These alkalies exist naturally in combination with organic acids, peculiar, like themselves, to the plant.

613. Three distinct, but closely allied alkalies are obtained from the cinchonas.

Cinchonia, of which the formula is $\text{NC}_{20}\text{H}_{12}\text{O}$, exists in the red and gray bark; quinia or quinine, $\text{NC}_{20}\text{H}_{12}\text{O}_2$, in the yellow bark; and aricina, $\text{NC}_{20}\text{H}_{12}\text{O}_3$, in the aricara bark, a tree closely allied to cinchona. These alkalies are all soluble in alcohol, and nearly or altogether insoluble in cold water; their taste is intensely bitter, and they crystallize in brilliant needles or prisms. They appear to be the

principles to which peruvian bark owes its febrifuge virtues, and the disulphate of quinine, $\text{Qu}_2\text{SO}_3 + 8\text{Aq}$, is extensively manufactured for medicinal purposes.

614. *Morphia*.—The narcotic virtues of opium are due to various alkaline principles, which have been obtained from it by the action of acids, and of alcohol. It seems probable that some of these are secondary products, and that they do not exist in the plant itself. The most important of these alkalies is morphia, the chief narcotic principle of the poppy. Morphia is almost insoluble in cold water, but dissolves freely in alcohol. Its solution is intensely bitter to the taste, and strongly alkaline. Morphia neutralizes the strongest acids, and forms soluble crystalline salts. It colours nitric acid red, forms a copious white precipitate with tannic acid, and a rich blue liquid with sesquichloride of iron. Its formula is $\text{NC}_{15}\text{H}_{20}\text{O}_6$. Its chlorohydrate, acetate, and sulphate, are much used in medicine as substitutes for opium.

615. *Strychnia*.—The nuts of the various species of the genus strychnos, are intensely poisonous, and owe their power to two alkalies, strychnia and brucia. Strychnia is the best known of these; it has an intensely bitter, somewhat metallic taste, and renders 700,000 parts of water strongly bitter. It is nearly insoluble in ether, absolute alcohol, and water, but dissolves readily in spirits of wine. It forms soluble crystalline salts, and is one of the most intense poisons known to us. Its formula is $\text{N}_2\text{C}_{44}\text{H}_{22}\text{O}_4$.

SECTION V.

COLOURING MATTERS.

616. *Indigo*.—One of the most remarkable nitrogenous products of vegetation, is indigo. It is se-

creted in the cellular tissue of various plants, and so long as the tissue remains perfect, it is colourless. But when the leaves begin to wither, the indigo absorbs oxygen, and acquires a blue colour. It is prepared by placing the leaves in large vats, in which they undergo a species of fermentation, and yield a yellow liquor, which contains the indigo. This is mixed with lime water, and the indigo slowly absorbs oxygen, becoming blue and insoluble. As thus prepared, indigo is a mixture of various bodies, from which it may be obtained by sublimation, as a rich purple vapour, which condenses into brilliant, purple, prismatic crystals, of a metallic lustre. The formula of this pure indigo is, $\text{NC}_{16}\text{H}_8\text{O}_2$. By the action of deoxidizing agents, indigo loses its blue colour, and becomes soluble in alkaline solutions. This colourless indigo is a compound of blue indigo with an atom of hydrogen, and it recovers its blue colour and insolubility, by the absorption of an atom of oxygen from the air. It may be prepared by mixing $1\frac{1}{2}$ parts of indigo, $2\frac{1}{2}$ of slaked lime, and 2 of sulphate of iron, with 60 of water, in an air tight vessel. The oxide of iron decomposes the water, the hydrogen of which combines with the indigo, rendering it colourless and soluble. Chlorohydric acid precipitates the white indigo from this clear solution, as a crystalline white powder. When cloths are dipped in this solution, the colourless indigo is precipitated in the fibre, and regains its blue colour in the air.

617. Indigo dissolves in sulphuric acid; and the solution retains the brilliant colour of the indigo, and is much used in dying by the name of Saxon blue. There appear to be two acid sulphates thus formed, one of which, called the *sulphopurpuric acid*, contains two atoms of each of its elements; and the other, the *sulphindyllic acid*, is a bisulphate of indi-

go; both of these acids form neutral salts with a single atom of alkali.

618. *Carbazotic Acid*.—By the action of acids and alkalies, indigo is resolved into several new compounds, the most important of which is the picric, or carbazotic acid. This acid is formed by the action of nitric acid on indigo; it crystallizes in brilliant yellow prisms, explodes by the action of heat, and forms detonating salts. Its taste is intensely bitter, and it forms an almost insoluble salt with potassa, which renders it one of the most delicate tests of that alkali. The formula of carbazotic acid is $C_{14}H_4NO_9 + Aq$.

619. *Red Colouring Matters*.—The principal red dyes are those obtained from the cochineal insect, brazil wood, log-wood, the roots of the madder, the flowers of the carthamus, and the resin of the lac insect. The colouring matter of all these substances is obtained in a solid form by dissolving them in a solution of alum, and precipitating the alumina by means of an alkali. The colouring matter falls in combination with it, and the precipitate when dried is known by the name of lake. These lakes are also obtained by means of chloride of tin, which forms richly coloured solutions, from which the colouring matter may be precipitated in combination with oxide of tin, by an alkali.

620. All the tints of the dyers may be produced by the combination of four principal colours, black, red, yellow, and blue.

The chief yellow dyes are the quercitron, or black oak bark, turmeric, fustic, and saffron. Black is produced by the pergallate and pertannate of iron.

621. *Mordants*.—Many of these colouring matters have so strong an affinity for wool, silk, and flaxen, and cotton fibre, that they do not wash out from the cloths that have been died with them.

Others again have so little affinity for organic fibre, that they readily wash out. These colours can be made fast colours, by first dipping the material to be dyed, in a solution of alum, or some other salt, the base of which has an affinity both for the fibre and colouring matter, which are thus made to enter into a permanent combination. A salt of this kind is called a *mordant* or basis; colours which adhere to cloth without a basis, are called *fast* or *substantive colours*; those which require one, *adjective colours*.

SECTION VI.

NEUTRAL NITROGENOUS COMPOUNDS.

A few colourless substances, possessing neither acid nor basic properties, are here grouped together.

622. *Asparagine*.—This proximate principle is contained in asparagus, the marsh mallow, and liquorice. It crystallizes in a rectangular octohedron, and in hexahedral prisms, is inodorous, and has a slightly cool, nauseous taste. It is soluble in water, but insoluble in ether and alcohol, and has no affinity for either acids or alkalies. Asparagine is resolved into a peculiar acid, termed the aspartic acid, and into ammonia, by being boiled with hydrated oxide of lead or magnesia, and it bears the same relation to this acid, that urea bears to cyanic acid. Anhydrous asparagine consists of $C_4H_5N_2O_6$, and aspartic acid of $C_4H_5N_1O_6$, so that the former is isomeric with aspartate of ammonia, $C_4H_5N_1O_6 + H_3N_1$, yet alkalies do not evolve ammonia, nor acids, aspartic acid, from asparagin. Crystallized asparagin, contains two atoms of water.

623. *Caffeine, Theine*.—One of the most remark-

able coincidences, which the researches in organic chemistry have brought to light, is the absolute identity of the active principle of the tea plant, and the coffee berry; two plants, which, although natives of countries remote from each other, and brought into use by nations of the most opposite habits, have become, from a sort of instinctive relish, the favourite beverage, and almost a necessary of life, with civilized man in all climates. *Caffeine* crystallizes in long brilliant needles, of a rich satiny lustre. It has a purely bitter taste, is soluble in water, has neither acid nor basic reaction, and contains more nitrogen than any other vegetable product. Its formula is $N_2C_8H_6O_2 + Aq$.

A nitrogenous resinous product, called *piperine*, is extracted from the various species of pepper. Its formula is $NC_{14}H_{19}O_9$.

SECTION VII.

THE ANIMAL FLUIDS.

624. The principal elements of the animal fluids have been stated to be fibrine, caseine, and albumen. They form the materials from which the tissues and skeleton of the living being are supplied with new matter. These, in conjunction with gelatine, and various earthy and alkaline salts, compose the animal structure.

625. *Blood*.—If fresh drawn blood be made to trickle over a plate of silver heated to 140° , it dries to a red, glossy, brittle mass, which yields by analysis, precisely the same proportions of nitrogen and hydrogen, carbon and oxygen, as proteine, so that the blood contains in a liquid form the identical constituents of flesh and cellular tissue. The specific gravity of blood is 1.055. When it is allowed to rest

it separates into a yellow liquid, called the serum, and a gelatinous red mass, called the clot or cruor. If it be examined under a microscope, blood will be found to consist of a multitude of red globules, floating in a nearly colourless liquor. These globules are circular or oval flattened discs, varying in different animals from $\frac{1}{8000}$ to $\frac{1}{1000}$ of an inch in diameter. They consist of a central colourless albuminous nucleus, surrounded by a membrane, which is coloured red by a peculiar principle, called *hæmatosine*. These red globules, along with the fibrine and a large portion of the albumen, form the coagulated mass, called the cruor. Lecanu found the blood to contain 13.3 per cent. of blood globules, .21 of fibrine, 6.51 of albumen, .67 of fatty and extractive matters, 1.05 of alkaline and earthy salts, and 78.26 of water and loss. Hæmatosine is a dark brown, tasteless, inodorous mass, which is insoluble in ether, alcohol, and water, but which forms blood red solutions with alkalies, and a rich permanent dye with bichloride of mercury. It constitutes but 4 or 5 per cent. of the red globules; and its formula, according to Mulder, is $C_{44} H_{22} N_3 O_6 Fe$.

626. *Milk*.—This fluid, in addition to caseine, contains sugar and oils, which like the analogous vegetable secretions, are destitute of nitrogen. The caseine exists in milk in two conditions, soluble and insoluble; the former remains in the milk, the latter separates with the cream. By contact with caseine, sugar of milk is converted into lactic acid. Berzelius found cream from cow's milk to consist of 4.5 per cent. of butter, 3.5 of caseine, and 92 of whey. Skimmed milk contains 2.6 per cent. of caseine and butter, 3.5 of sugar of milk, .6 of extractive and lactic acid, .17 chloride of potassium, .255 of earthy and alkaline phosphates, and 92.875 of water.

627. *Mucus and Gastric Juice*.—The internal surface of the alimentary canal, is kept constantly

moist, by a thick tenacious mucus, closely resembling the solution of *cerasine*, but containing nitrogen. When any substance is introduced into the stomach, there is copiously secreted, in addition to the mucus, a colourless pale yellow liquid called the *gastric juice*. This fluid contains about two per cent. of common salt and sal ammoniac, and a portion of free chlorohydric acid, and possesses the remarkable property of softening the food, and converting it into an uniform gray pulp, called *chyme*, from which the absorbent vessels take up the nutritious portions. It owes this property to the presence of an organic principle, called *pepsine*, which excites, in the food that enters the stomach, a true fermentation, converting it into chyme, by communicating to it the molecular change which its own particles are undergoing, in the same manner as ordinary ferment gives rise to the changes which convert sugar into alcohol.

628. *Bile*.—As soon as the *chyme* has passed from the stomach, it receives the addition of *bile*, a liquid which distils drop by drop from the gall bladder into the intestinal canal, and which converts the chyme into *chyle*. This is an opaque, white, milky fluid which contains the same elements as blood, and is collected from the innumerable vessels, at the extremity of which it is taken up from the intestines, and poured into the venous blood before the latter returns to the heart. The bile, which thus converts the digested food into *chyle*, is secreted by the liver from the venous blood which passes through it in the course of circulation. It is a fluid of a greenish yellow colour, which contains 91.5 per cent. of water, united with resins, a fatty acid, soda and common salt. The principal element of bile is the *choleic acid*, which is a bitter, yellowish white, brittle mass, soluble in ether and alcohol, and forming soaps with alkalies. It exists in the bile in combination with

soda, and its formula, according to Liebig, is C_7, N_3, H_{66}, O_{22} .

629. *Urine*.—As it is the office of the liver to abstract from the venous blood, in the shape of bile, all excess of carbon which it contains, so it is the function of the kidneys, to separate from the arterial blood, all the products which are rendered unfit for circulation by containing an excess of nitrogen. None of the animal fluids is subject to such changes in its constitution, from age and disease, as the urine. In a healthy person it contains 93.3 per cent. of water, 3 of urea, 1.7 of lactic acid, .1 of uric acid, and nearly 2 per cent. of alkaline and earthy phosphates and sulphates, and common salt.

630. *Urea*.—Urea is obtained in brilliant white quadrangular prisms. It is an inodorous, neutral substance, of a nitrous taste, soluble in water, and producing great cold during its solution. Its formula is $N_2C_2H_4O_2$. The solution of urea in pure water continues long unaltered; but if any ferment is present, a change of constitution takes place, it appropriates to itself four atoms of water, and is converted into 2 atoms of carbonate of ammonia; $N_2C_2H_4O_2 + H_4O_4$, becoming $2(CO_2 + NH_4O)$. Urea is isomeric with cyanate of ammonia, $NC_2O + NH_4O$; and may be artificially prepared by mixing solutions of cyanate of silver, and chlorohydrate of ammonia. Chloride of silver is precipitated, the remaining solution does not yield cyanic acid with acids, nor ammonia with alkalies, but crystallizes into quadrangular prisms identical with urea.

631. *Uric Acid*.—This acid is found in the urine of carnivorous animals, and in the dry white excrement of serpents. The latter consists chiefly of urate of ammonia. Pure uric acid is white, tasteless, inodorous, and very sparingly soluble in water. It reddens litmus paper and forms crystalline salts. Its

formula is $\text{N}_4\text{C}_{10}\text{H}_4\text{O}_6$. The bony concretions, which are formed in the joints in gouty patients, consist of urate of soda.

By the action of nitric acid, uric acid undergoes a series of very remarkable changes, giving rise to compounds of great interest in a theoretical point of view, and some of them possessing singular beauty of colour.

PART THIRD.

THE HISTORY OF CHEMICAL PHILOSOPHY.

CHAPTER I.

THE CHEMICAL KNOWLEDGE OF THE ANCIENTS.

632. Although the science of chemistry bears every mark of being upon the eve of great changes, which will separate its future from its present, by even a wider interval, than separates its present from its past conditon, there is perhaps no example in the whole range of science, of clearly demonstrated doctrines, more contradictory in appearance to all our ordinary conceptions, than are to be found in its domain. The present is separated from the past, the scientific view, from the popular notions, by so wide a gulf, that the study of chemistry would be deficient in some of its most instructive lessons, if we were to omit the history of its rise and progress.

633. This science being the developement of the laws which govern the mutual action of bodies, and the changes consequent upon their intermixture, the elements of a rude chemistry must have existed in the earliest ages, as soon as men began to explore the material world around them, and to apply to their own use the qualities which they thus discovered. We must suppose that many of the early

discoveries were the result of accidental combinations; and yet the knowledge which the fathers of mankind acquired, and the arts they practised, seem more like the results of a wisely directed instinct, which is but another name for the inspiration of superior power, than the slow and irregular advances of blind chance and necessity; so greatly are they superior to the arts known to those branches of our race, who having lost the traces of that original knowledge, and sunk into a barbarous ignorance, have been compelled to toil up the steep and almost inaccessible paths, which lead back to industry and civilization.

634. It is difficult, perhaps impossible, to ascertain the exact extent to which the ancients practised the chemical arts. Of chemical theory they were absolutely ignorant; but they could not fail to become acquainted with the more common and useful metals, to discover many of the salts which exist in a state of nature, and to apply their properties in some of the various processes and manufactures with which they were acquainted.

635. We cannot, in many cases, determine the substances designated by names which we now apply to familiar and well known objects; objects, which, we are apt to think, have always been so called, while in fact the names are of far greater antiquity than the discovery of the substances themselves, and have been variously applied according to the state of the arts and civilization. In the ancient languages, moreover, there are many terms for which we have no modern equivalents, or of which the only translation that can be given is conjectural; so that at every stage of the inquiry into the arts and knowledge of the ancients we meet with doubts and difficulties not easily to be resolved.

636. Seven metals were known to the Greeks and Romans, viz. gold, silver, copper, iron, lead, tin, and

mercury. Of these, the first five appear to have been known to mankind in the earliest ages. There seems little doubt that gold was the first of these metals which attracted the attention of man. Being found in masses of sufficient magnitude to exhibit its properties of fusibility, malleability, and ductility; its beauty of colour, its brilliancy, and unalterability by the air and by fire, rendered it an object of universal admiration and eager desire. Its discovery must be regarded as an era in the history of the arts, for it possesses properties so peculiar, and so useful, so different from most of the rude materials which met their gaze, that men must have had their curiosity strongly excited, to learn whether there were any other substances possessing similar qualities of fusibility, ductility, and malleability. The discovery of silver, of copper, and of iron, metals which are occasionally found native, was probably the first fruits of this search; if indeed it was not accidental, and contemporaneous with that of gold, for we know that these metals were in use before the flood. It is not an unlikely conjecture, that the accidental presence of some of the ores of these metals in the vessels in which the operation of melting was performed, or in the ground where a great fire had been kindled, led the way to the knowledge, that there were stony substances from which these precious materials could be extracted. The presence of native silver and copper in frequent association with stones of certain characters, was a sufficient indication of their existence in these ores. As no mineral substance was more likely to excite their attention from its weight and metallic lustre, or would sooner reward their labour by yielding up its metal, than galena, it is a very natural conjecture, that the discovery of lead was one of the first fruits of these rude investigations. The frequent union of the ores of iron with those of copper, would soon lead to the discovery of

the art of obtaining that metal, if its accidental production by fire in the way pointed out, be not more probable.

637. Gold and silver were melted, and cast, and hammered, into various forms; and were also beaten into thin plates, which were used in covering wood and other materials. The extreme thinness which has been given to those metals by modern goldbeaters, is, however, an art of recent date.

638. The Egyptians, before the time of Moses, knew the process for hardening iron, so as to render it fit for axes and other cutting tools. Five hundred years later, however, the use of copper for these purposes still continued among the Greeks, who had no other swords, at the time of the Trojan war, than those made of copper hardened by fire.

They afterwards learned the property which iron possesses, of being welded, and knew the art of converting that metal into steel. But it is a remarkable proof of the looseness of their habits of observation, that both the Greeks and Romans attributed the hardening of soft iron by sudden cooling, to a peculiar property of certain waters, which acquired thereby extraordinary celebrity. Like most of the arts and learning of the age, the knowledge of iron was brought from the East, and the word Chalybs was the name of a tribe on the Euxine, from whom the Greeks learned the use of the metal, just as our term for all the finer kinds of pottery, is an acknowledgment that we derived the art of making them from the Chinese.

639. The name Stannum, which we translate Tin, and which was, without doubt, subsequently applied by the ancients to that metal, appears to have originally denoted an alloy of lead and silver, from which the art of separating the more precious metal was unknown. The tin of ancient commerce was procured by the Phenicians from Spain and Britain.

the inexhaustible mineral riches of the latter country having been thus early known.

The ancients alloyed copper with lead and tin, and carried to great perfection the art of casting statues of bronze, which was an alloy of these metals in various proportions.

640. Although ignorant of the existence of zinc as a peculiar metal, they were well acquainted with the alloy of that metal and copper, and with the ore of zinc, called calamine, which was used then, as it is now, for obtaining brass.

641. Lead was in common use among the Egyptians in the time of Moses. Like tin, it was chiefly furnished by the Phenicians, who obtained it from Spain and Britain. It was beaten into thin sheets, as at present, and was cast into pipes for the conveyance of water.

642. Mercury was found in the mines in its native state, and was also obtained from cinnabar. It is not mentioned by Moses, or by Herodotus, so that its discovery is probably of later date than that of the other metals, of which we have been speaking. The ancients knew that it dissolved gold and silver, lead, copper, and tin, and applied it to the purpose of gilding, in the same manner as is now done.

643. It seems probable that Bismuth was occasionally seen by the ancients, but that it was not distinguished by them from tin or lead.

644. The sulphuret of antimony was used by the Asiatics, as it is to this day, for blackening the eye brows, and what is not a little singular, the term alcohol, now used only for spirits of wine, was originally applied to this powder. The red and yellow sulphurets of arsenic were known as pigments. The black oxide of manganese was employed, as now, by the ancient potters, without its being known, however, that it contained a distinct metal.

645. The ancients were acquainted with many

other pigments prepared from the metals, such as red and white lead, cinnabar, the ochres, and the blue and green carbonates of copper. They were acquainted with alum, and copperas, and knew their use in dying. The Egyptians knew the art of calico printing, and the nature of mordants, for Pliny describes with great clearness the process still employed in India for printing in colours. "There exists in Egypt," says he, "a wonderful method of dyeing. The white cloth is stained in various places, not with dye stuffs, but with substances which have the property of absorbing colours. These applications are not visible upon the cloth; but when they are dipped into the hot caldron of the dye, they are drawn out, an instant after, dyed. The remarkable circumstance is, that though there be only one dye in the vat, yet different colours appear upon the cloth; nor can the colour be afterwards removed."—*Plinii Hist: Nat.* xxxv. 11.

So great a degree of skill implies a considerable knowledge of dyeing materials, and of mordants.

646. Nitre was discovered in India and China, and the explosive mixture which it forms with sulphur and charcoal was known in the latter country before the Christian era, although it was not applied to the purposes of war. It is altogether uncertain when this salt was introduced into Europe, but the nitre of the Greeks and Romans was natron, the mineral alkali, and they knew nothing of the modern nitre. Natron was used by them in the manufacture of glass.

647. This material was known to the ancient Egyptians, and was probably an accidental and often made discovery, for the chance to which it is attributed must often have happened. Some Phenician merchants, it is said, landing near Berytus in Syria, with a cargo of natron, and having nothing wherewith to support their kettles, while they were dressing their

food, took lumps of the natron for that purpose; the fire melted the salt, and fused it and the sand of the shore into glass. The Egyptians coloured their glass with various metallic oxides, and formed it into vessels, and vases, and beads. The principal use made of it by the Phenicians, was for plates to line the walls and ceilings of their apartments.

648. The art of making soap was practised by the ancient Germans and Gauls, but was known neither to the Greeks nor Romans till the time of the Roman emperors, when soap came into use as a pomatum.

The only acid known to the ancients, was the acetic, as obtained by fermentation.

They manufactured stone and earthen ware, and porcelain of a fine quality. They knew the use of calcined plaister of Paris in taking moulds, and prepared a mortar which hardened under water.

Wine was universally known, and the Egyptians made a fermented liquor of barley. Beer was the favourite national drink of the Gauls and Germans. There is, however, no evidence that the ancients had any knowledge of the art of distillation.

649. Such seems to have been the amount of knowledge possessed by the ancients in these particulars. That knowledge remained for a long time nearly stationary, and it was not till the conquests of the Saracens overturned the old, and laid the foundation of a new order of society, that it began to advance. These conquests, by infusing new vigour into the decaying institutions of Europe, and mingling the learning of the east with that of the west, revived industry and commerce, and created anew the chemic arts.

CHAPTER II.

THE ALCHEMISTS.

650. The Saracen caliphs of Bagdad and Spain, were the great patrons and restorers of the learning of the middle ages. The caliphs of Cordova, from the eighth to the tenth century, and more especially the three Abdalralimans, and Alhakem, carried the splendour of their monarchy to the highest pitch. They were probably the best and wisest sovereigns that ever sat on the throne of Spain. Alhakem established an academy at Cordova, which was for several years the most celebrated in the world. In the tenth century it contained a library of two hundred and eighty thousand volumes. In the twelfth century, there were no less than seventy public libraries in Mahometan Spain. Cordova produced one hundred and fifty authors, Almeria fifty-two, and Murcia sixty-two.

The caliphate of Bagdad was the great centre of learning in the east, as that of Cordova was in the west. In the middle of the eighth century, Almanzor founded the celebrated school of Bagdad, which numbered at one time more than six thousand scholars, who thronged thither from all parts of the civilized world. He established public hospitals for the sick, and laboratories for the preparation of medicines. These institutions gradually fell into decay, but were resuscitated in the thirteenth century by Mostanser; and Haroun al Raschid, Almamon, and their successors, patronized science with a zeal and liberality not inferior to that which animated the monarchs of Cordova.

Under the genial protection of these caliphs, learning of every kind flourished. The Arabs eagerly

cultivated the Greek philosophy and mathematics, but the sciences to which they directed their principal attention, were those connected with the healing art. We find accordingly that they laboured incessantly to discover the effects upon the human frame, not only of all the plants which gave promise of medicinal efficacy, but that they explored for this end, with the greatest eagerness, the almost unopened mine of chemistry. Every thing here was to be begun anew; the sensible properties of chemical substances, and the manner in which they acted upon each other, had to be examined; and the novelty of the research, and the inexhaustible field of observation which was thus opened, drew crowds of votaries into these hitherto untrodden paths.

651. They went on for ages groping in the dark, pursuing their way, they knew not whither, following every accidental gleam of light, wasting the strength of giants, and the acuteness of the greatest genius, in barren and almost useless labours. Yet they were unconsciously preparing the soil for the rich harvest which their successors reaped, and it will well repay the curiosity of philosophical research, to trace the steps by which the science has advanced, from the ignorance of the Greeks and Romans, through the absurdities and follies of alchemy, to the sober and patient research which has led to the brilliant discoveries of our own times.

652. The Arabians had brought from the east the idle hope of being able to transmute the common metals into gold. Snatching at the similarity of properties of many of those bodies, they fancied that tin, and lead, and copper, only differed from silver and gold in the addition of some ingredients, which rendered them less ductile and unalterable, and that there must be some means of separating the perfect metals from the dross and impurities that thus debased them.

The success which attended their rude attempts in the healing art, led them to suppose that behind the curtain which veiled the secrets of nature, must be concealed remedies of greater and of universal power, able to drive pain, and disease, and death, from the earth.

These vain expectations set in motion the two most powerful springs of action, the love of life, and the love of wealth, which impelled men in the search after new processes and combinations in chemistry, with a zeal and devotion which could not probably have been supplied by any other motives.

653. The writings of Geber are the earliest records, now extant, of the progress which chemical knowledge had made between the Christian era and the middle ages. Geber was the assumed name of a native of Harran in Mesopotamia, who lived in the eighth century, and of whose personal history little or nothing is known. He was acquainted with metallic arsenic, in addition to the metals known to the ancients, and he regarded them all as compounds of mercury and sulphur. Of these gold and silver are perfect metals: gold consists of the most subtile substance of mercury, as is proved by the ease with which the latter metal dissolves it; for mercury can dissolve nothing that is not of its own nature. Silver, like gold, consists of much mercury with little sulphur; but its sulphur is white, while that of gold is red. The other metals were composed of earthy mercury and fixed sulphur; and they were all capable of being converted into gold and silver by altering the nature and proportions of their sulphur and mercury. This change could be effected by the philosopher's stone, or the medicine, as he more commonly called it.

Geber was acquainted with the process of distillation, by which he purified vinegar, and he applied the term spirit, to sulphur, arsenic, and other volatile

solids. He is the first writer who gives an account of nitre, and he prepared what he called dissolving water, by subjecting to distillation a mixture of sulphate of iron, nitre, and alum. He noticed the red fumes which are disengaged in the process, and used the liquid for dissolving silver. He was acquainted with crude sal ammoniac, and used its solution in his dissolving water for liquefying gold. He was acquainted with potash, soda, and alum; and by exposing the latter to a red heat in a glass retort, he obtained a weak sulphuric acid, which he preserved as a valuable menstruum. Geber mentions copperas, the sulphate of iron, which, as well as alum and nitre, he purified by solution and recrystallization. He made corrosive sublimate, cinnabar, and red precipitate; he prepared precipitated sulphur by dissolving sulphur in caustic alkali, and pouring distilled vinegar into the solution. He knew the combustibility and volatility of metallic arsenic.

654. When we compare the knowledge possessed by Geber, with that of the Romans, it is evident that very important additions had been made to the stock of chemical facts. The discovery of sulphuric, nitric, and nitromuriatic acids, of arsenic, of the mercurial salts, and of the solubility* of sulphur in the alkalies, mark an era in the science, and whether or not they were the discoveries of Geber, entitle him to the epithet of the patriarch of chemistry, although he veiled his descriptions in the mystical jargon of the alchemists, so as to render them almost unintelligible.

655. From the time of Geber to the beginning of the twelfth century, there are few changes in the state of chemical knowledge of sufficient importance to attract attention. But the returning wave of the Crusades, wafted back to Europe the knowledge and the arts of the East, and greatly multiplied the number of the searchers after the Universal Medi-

cine, as the Philosopher's Stone was called, and the Elixir of Life. Too many of these were crafty impostors, or their ignorant dupes, who added little to the stock of knowledge. A few great men, however, appeared amid the surrounding darkness, who brought to light some important chemical facts.

656. The illustrious Roger Bacon, a native of England, flourished in the thirteenth century. Among a variety of less important discoveries, he may claim the invention of gunpowder. "From saltpetre and other ingredients," says he, "we are able to form a fire which will burn to any distance." In another place he says, "a small portion of matter, about the size of the thumb, properly disposed, will make a tremendous sound and corruscation, by which cities and armies might be destroyed." The following curious passage is also found in his writings. "*Sed tamen sales petre luru mone cap urbe, et sulphuris, et sic facies tonitrum si scias artificium.*" The words *luru mone cap urbe*, according to the fantastic fashion of the age, were an anagram of the words *carbonum pulvere*, framed to conceal his meaning from vulgar understandings; and there can be no doubt that they were designed to record, and yet to hide his acquaintance with the art of manufacturing gunpowder.

657. In the writings of Arnold; a native of Villa Nova in Provence, who was born in 1235, we meet with the first distinct notice of spirits of wine, a preparation, the extraordinary effects of which on the human system, and its qualities as a solvent, rendered it an acquisition of the greatest importance to the empirics and pretenders of the age.

658. Raymond Sully, another alchemist of the same time, knew how to concentrate alcohol by distillation from alkali, and he prepared the volatile alkali by the destructive distillation of bones, and

more particularly of the horns of the stag, which process is the origin of its ancient name of spirits of hartshorn.

659. To Basil Valentine, in the latter part of the fifteenth century, we are indebted for our knowledge of metallic antimony, and its principal preparations. Paracelsus was the boldest, and the most famous, of all these daring innovators. He trampled on all authority, he united in himself all the extravagances of all his predecessors, and he awakened the age from its slumbers, by calling every thing in question, by trying every thing, and innovating in every thing. Yet the writings of Paracelsus do not add much to our stock of chemical knowledge. We find that zinc and bismuth were known to him, and he has mentioned or discovered many combinations and salts not before noticed. But the discovery of alcohol, and its powers as a menstruum, had directed the attention of physicians to remedies from the vegetable kingdom, and the alcoholic tinctures which thus took the place of syrups and confections, constituted a great advance in the science of pharmacy, although they added little to the list of facts in chemistry.

660. Van Helmont, a German, who lived in the early part of the seventeenth century, is the first who appears to have suspected that there were different kinds of air, and who used the term gas. He knew that that which is given out in the fermentation of beer and wine, extinguished flame, and he asserted that it was identical with that found in the Grotto del Cane, near Naples. He knew that the air evolved during the putrefaction of animal bodies was inflammable, but it does not appear that he had noticed any other qualities of gases than those which relate to their action on flame.

661. Glauber, a German, who lived at Amsterdam about the middle of the seventeenth century,

was one of the most industrious experimenters of the age. He discovered many chemical compounds which bear his name, and was the first who prepared chlorohydric acid, which he called spirit of marine salt. He obtained sulphuric acid by distilling sulphate of iron, he greatly improved the process for preparing nitric acid, and added many new instruments and apparatus to the stock already in use.

662. To Brandt and Kunkel, two indefatigable chemists of the same age, we are indebted for the discovery of phosphorus. It was first obtained by the former, who was a chemist of Hamburg, in the vain attempt to extract from urine a liquid capable of converting silver into gold. He showed a specimen to Kunkel, but refused to tell him how he obtained it. Kunkel immediately set himself to work, and after three or four years of labour, discovered the process for making it. Among the most important inventions of the age, was that of the thermometer, which was originally contrived by the academicians of Florence, but was brought into notice by Fahrenheit, a Dutch merchant, who devoted himself to the making of philosophical instruments.

663. The close of the seventeenth, and the early part of the eighteenth century, are the eras of the foundation of chemical science. The great accumulation of facts, rendered some classification of them necessary, and the works of Boer, a learned Dutch physician, and of Lemery, an apothecary of Paris, the first formal treatises that have any claim to a philosophical spirit, were the results of this necessity.

CHAPTER III.

THE STAHLIAN THEORY.

664. The first attempt at a philosophical theory, which had any influence on the progress of the science, was by a German named Beecher, who furnished Ernest Stahl with the original ideas of the celebrated theory of Phlogiston. It was the genius of the latter which rendered this doctrine the creed of the science for nearly a century. He was a native of Anspach, and a physician of great eminence, but his chief merit is the attempt which he made, to explain the principal phenomena of chemistry by a simple and ingenious theory. Stahl found that the sulphurous and phosphoric acids, into which sulphur and phosphorus were converted by burning, were reconverted into sulphur and phosphorus, by being heated with inflammable bodies. He therefore inferred that combustible bodies contain a peculiar principle of inflammability, with which they part in the process of combustion. This principle he called phlogiston, and supposed that sulphur and phosphorus were compounds of phlogiston, with sulphurous and phosphoric acids. Admitting the existence of this principle, the proof from experiment seemed at the time to be complete. For all inflammable bodies are converted by combustion into substances incapable of being burnt, and have their inflammability restored by the action of another inflammable body, which thereby loses the property. The theory which explained these changes, by supposing that a principle of inflammability had been transferred from one body to the other, seemed the simplest and most beautiful that could be devised.

665. Unfortunately it had one fundamental error,

which was even in that age detected, but the detection of which did not, in the infancy of science, attract the notice it deserved. If sulphur and phosphorus, in burning, part with a portion of their substance, the product of combustion should be less than the quantity burnt. Brun, an apothecary at Bergerac, in France, melted two pounds six ounces of tin, and converted it into a calx, which weighed 7oz more than the tin employed. This experiment was performed as early as the year 1626, a century before the publication of the theory of Stahl. Surprised at this circumstance, he communicated it to John Rey, a physician of Perigord, who made it the subject of a tract published in 1630, in which he ascribes the increase of the weight, to the solidification of the air. Had this fact presented itself in the same lights, to a mind as bold and comprehensive as that of Stahl, how much would the progress of Chemistry have been accelerated! for it is the key to some of the greatest mysteries of the science.

That the calcination of the metals was a phenomenon of the same kind as the combustion of inflammable bodies, was soon perceived: for many metals burn with a brilliant flame when calcined at a great heat. The celebrated Robert Boyle attributed the increased weight of the burnt or calcined body, to the solidification of the matter of heat, with which he supposed the metal to have combined; but his opinion does not appear to have gained much attention. When the difficulty struck the phlogistic philosophers, they were driven to the necessity of supposing their phlogiston to possess a principle of levity, so that by its union with bodies it actually lessened their weight; and this opinion, absurd as it now seems, satisfied for a time the disciples of Stahl.

666. It was the great merit of the phlogistic theory, that it provided a principle of classification, according to real distinctions in nature; the changes which

bodies undergo by combustion, being in fact the foundation on which the true science of Chemistry is now built. The simplicity and comprehensiveness of the doctrine attracted numerous labourers into the vast field of chemical research, and the first eighty years of the eighteenth century were illustrated by the labours of men who must ever be regarded as the patriarchs of experimental research, and whose labours and works still retain their value. Some of the most illustrious of these men were Germans, attracted to Berlin by the fame of Stahl, and of the school which he there established. Scheele, Neuman, Margraaf, Bergman, Klaproth, and Pott, in that country; Reaumur, Hellot, Macquer, Du Hamel, and Baumè, in France; Mayow, Hales, Rutherford, Black, Cavendish, and Priestly, in Great Britain, were the most distinguished of these philosophers. Neuman laboured chiefly in the examination of organic substances; Bergman and Klaproth in the analysis of minerals. The researches of Scheele fill a large space in the history of Chemistry. He discovered, and carefully examined the properties of fluoric acid, in 1771; he ascertained the nature of black oxide of manganese, the peculiar character of baryta, the existence of nitrogen as an element of ammonia, and was the first who obtained, and examined the properties of chlorine. In conformity with the Stahlian theory, he called this gas dephlogisticated marine acid; for it was obtained from this acid by a process, analogous to that by which inflammable bodies are deprived of their phlogiston. He was one of the discoverers of azote and oxygen; he ascertained the composition of prussian blue, and the properties of cyanhydric, or, as it was then called, the prussic acid. He examined the acids evolved in various fruits and vegetables, and his essays will bear a comparison with the best productions of our own times, in accuracy, skill, and ingenuity.

667. Dr. Rutherford, of Edinburgh, discovered in 1772, that atmospheric air which has been breathed, acquires new properties, and announced the existence of a new species of air, which did not precipitate lime water, and yet was incapable of supporting life or combustion. The greatest advance made at that period, in chemical science, was due to Dr. Black of Edinburgh. By a series of ingenious experiments, this philosopher, in investigating the changes which chalk and magnesia undergo in the fire, discovered that they lost weight, and that this loss of weight was occasioned, like their effervescence with acids, by the escape of an aeriform substance. He announced that chalk and magnesia consisted of a caustic earth, rendered mild by combination with this air, and which he therefore called *fixed air*, and which he afterwards proved to exist in all the mild alkalies. Dr. Black's greatest service to science was the discovery of the fact, that a quantity of heat combines with solids in becoming liquids, and with liquids in becoming vapours, and that it is given out by them when they return to their former state. He also discovered that bodies differ in the quantity of heat requisite to effect equal changes of temperature. These two capital discoveries of the nature of latent, and of specific caloric, may be regarded as laying the first sure foundations of the philosophy of heat, and they were demonstrated by Dr. Black in the most forcible and beautiful manner.

668. The great chemical discoveries of the eighteenth century, those of the nature and properties of oxygen gas, and of the composition of water, were claimed by several individuals. Scheele, in Germany, and Priestley, in England, obtained the vital air, as it was first called, independently of each other. The account which the latter gives of his discovery is worth recording. He had filled a glass jar with mercury, and inverted it in a basin of the same;

some *red precipitate of quicksilver* was then introduced and floated upon the quicksilver in the jar; heat was applied in this situation by a burning lens, "I presently found that air was expelled from it very readily. Having got three or four times as much as the bulk of my materials, I admitted water into it, and found that it was not imbibed by it. But what surprised me more than I can well express, was that a candle burned in this air with a remarkably vigorous flame, very much like that enlarged flame with which a candle burns in nitrous air exposed to iron or liver of sulphur; but as I had got nothing like this remarkable appearance from any kind of air besides this peculiar modification of nitrous air, and I knew no nitrous air was used in the preparation of mercurius calcinatus, I was utterly at a loss how to account for it."—Exp. and Obs. on different kinds of Air, &c., vol. ii. p. 107. Birmingham, 1790.

Priestley, in conformity with the doctrine of Stahl, supposed that this air owed its remarkable properties as a supporter of combustion, to its being deprived of phlogiston, and that the phenomenon of combustion was occasioned by the transfer of phlogiston from the burning body to this "dephlogisticated air." We owe to Dr. Priestley the perfection of the pneumatic apparatus, the use of the mercurial bath, a knowledge of the properties of the protoxide and dutoxide of nitrogen, the discovery of chlorohydric acid gas and ammoniacal gas, besides a vast number of experiments and observations, that embraced the whole range of chemistry as it then extended.

669. About the same time, Henry Cavendish, an English nobleman of a recluse and studious life, devoted a singularly acute and patient mind to these researches. He was the first (A. D. 1766) who obtained hydrogen gas by the action of dilute acids

upon the metals, and who examined its properties. He also first noticed the formation of moisture, when this inflammable air is burned in a tube. It has been asserted, that the discovery of the composition of water is fairly to be added to the trophies which render the great name of James Watt illustrious; but the recent publication of his original manuscripts, prove that we owe both the first hint, and the complete demonstration of this capital discovery to Cavendish.

CHAPTER IV.

THE LAVOISIERIAN CHEMISTRY.

670. While the chemists of England and Germany, were thus extending the bounds of knowledge by the rapid accumulation of facts, a school was arising in France, which, guided by more profound and philosophical views, soon changed the aspect of the whole science, and laid the foundations anew in a juster and more skilful induction.

Antoine Laurent Lavoisier, who is placed by common consent at the head of these celebrated men, was an opulent French gentleman, who devoted the leisure which he could draw from the duties of a public station to the pursuits of science. In 1774, he entered the field of chemical research, in which, although he did not add so many new facts to our stock of knowledge as some of his cotemporaries, he surpassed them all in comprehensive views and sagacious theory. The virtue and mildness of his private character, and the munificence with which he patronized science and the arts, exposed him to the suspicions and hatred of the madmen who rode upon the storm of the revolution, and he perished

on the scaffold in the prime of life. His only request to the officer who arrested him was, that he might be allowed to complete an important experimental investigation in which he was engaged, and it was heard, like the prayer of Archimedes to the Roman soldier, with disregard and contempt.

671. The first great service which Lavoisier rendered to the science was his proof of the real nature of combustion. He demonstrated, in an extensive and beautiful series of experiments, that combustion is the union of the burning body with the vital air of the atmosphere, and that the calcination of the metals is another case of the same combination. He recovered the air from the bodies with which it had united, and showed that the weight of the product is in all cases equal to that of the air and of the body which has been consumed. He made Dr. Black's doctrine of latent heat the foundation of his theory of combustion, and contended that the heat and light given out in the process, are due to the latent heat of the vital air with which it parts in becoming solidified. The explanation was ingenious and plausible, and was generally received at the time, but subsequent researches have shown it to be insufficient to account for their evolution in many cases of combustion.

672. The researches of Lavoisier, even when not marked by strict originality, are masterly specimens of philosophical skill. It was thus that he pursued the investigation into the composition of water and of fixed air. He showed that the latter is always a compound of charcoal and vital air, that it is always produced when that substance is burned, that its weight is equal to that of the charcoal and the vital air consumed, and that it can be again converted into charcoal. He was the first who examined the nature of the change which the diamond undergoes *when it is dissipated by exposure to an intense heat, and astonished the world by announcing, as the*

startling result of his researches, the identity of diamond and charcoal.

673. The name of Lavoisier is associated with that of Guyton Morveau, Berthollet, and Fourcroy, in the reformation of chemical nomenclature. They found the science overloaded with barbarous synonyms, with names either without meaning, or conveying erroneous notions of the substances they designated; framed according to the caprice of the inventor, and embarrassing the student by the false impressions they created. They therefore undertook to frame a strictly philosophical language of chemistry, every term of which should have a precise signification, expressing, if it belonged to a simple body, some peculiar property, and if it were the name of a compound, designating the composition of the substance. They executed this novel project with consummate sagacity and success, and the beauty and simplicity of its new nomenclature, contributed greatly to render chemistry, what it soon became, the most popular science of the day. Even where their premature generalizations involved them in theoretical error, which vitiated the correctness of their language, there is no difficulty in adapting the nomenclature to the new discoveries without impairing its symmetry.

674. The details of this system have already been given, from which it is easy to see the errors into which they fell in regard to certain general laws. The only acids, the composition of which was known to them, were those formed in the process of combustion, or proved by analysis to contain vital air. They therefore inferred that this air was the principle to which all acids owed their peculiar properties, and they called it oxygen gas. The error consisted in too hasty a generalization, and long misled the investigations of philosophers. The first exception that was discovered to this rule, was by Scheele, who could find no oxygen in a careful analysis of

prussic acid. An error more material in its consequences was the supposed constitution of the substance formed by the addition of oxygen gas to muriatic acid. Supposing the resulting body to be a compound of the two, it was inferred that the muriatic acid was a combination of oxygen and an unknown base, which was capable of a still higher degree of oxygenation. This second compound was therefore called oxygenated, or oxymuriatic acid, and its supposed constitution was for many years unquestioned. Its properties were so peculiar, as reasonably to excite doubt of its being in any respect an acid; but these did not lead to any suspicions of its real nature, until, in the year 1809, Gay Lussac and Thenard announced that its formation was explicable on the supposition of its being an elementary substance. Sir Humphrey Davy, about the same time, subjected this body to the action of the most powerful decomposing agents, without its undergoing any change, and arrived at the conclusion that it must be regarded as a simple undecomposed body. On this view, muriatic acid was formed by the combination of hydrogen with oxymuriatic acid, and, when the former is converted into the latter by the addition of oxygen, water is always formed. These views were established by careful experiment, and strict induction, and they entirely changed the face of the science, and soon received a powerful confirmation by the discovery of the closely allied elements of iodine and bromine. Chemists no longer regarded oxygen as the sole acidifier, but reckoned chlorine, as the oxymuriatic acid was now called, iodine, bromine, sulphur, and even certain compound bodies, such as cyanogen, in the same class.

675. To Sir Humphrey Davy we are also indebted for the great discovery of the metallic properties of the bases of the alkalies and earths, and for a long series of successful researches in every depart-

ment of the science. He seized hold of the electricity evolved in the voltaic circuit, and showed it to be the most powerful agent of decomposition that had hitherto been known. The researches to which the powers of the voltaic pile had given rise, brought to light the fact, that when compound bodies were decomposed by the electric current, acids were constantly evolved at one pole, and alkalies at the other. The idea was natural, that the attraction which held bodies together, and which was thus neutralized by the electrical fluids, must be the antagonist force to that which destroyed or suspended it, and that all bodies in nature are endued with resinous or with vitreous electricity, forces which are therefore identical with the cause of chemical attraction. The most subtle and profound investigations that science has witnessed since the optical researches of Newton, I mean those detailed in the electrical papers of Faraday, have given to this theory a solidity and an importance, which make it at the present time the central point of interest in the science of chemistry.

CHAPTER V.

THE ATOMIC THEORY.

676. While Chemistry was thus advancing with rapid strides towards the point to which we have conducted its history, the facts had been slowly accumulating, which became the data for the most important generalization that had yet been attempted. Although Ernest Stahl had seen the necessity of supposing that bodies are endued with different degrees of attraction, in order to explain the changes which take place; the law was first laid down with precision by Geoffroy, in 1718. "In all cases," says he, "where two substances which have any

disposition to combine, are united, if there approaches them a third, which has more affinity with one of the two, this one unites with the third and lets the other go." Geoffroy exhibited the degrees of this affinity, as respected the then known acids and bases, in the form of a table, placing that substance at the head of the column of affinities, which separated the substance whose affinities were thus given from all other bodies; and ranking the others in the order of their power of decomposition. These tables were the result of numerous experiments, and formed the most valuable body of facts that had as yet been published in the science.

677. In 1775, Torbern Bergman published his celebrated work on elective attractions, in which he extended and confirmed the law of Geoffroy, corrected his tables and entered into extensive investigations to ascertain the proportions in which bodies combine. Two years afterwards a German, named Wenzel, published a treatise on the doctrine of the affinities of bodies, which contained many accurate analyses. He found that when two neutral salts decompose each other, the resulting salts are also neutral, and he announced the law, that the elements of bodies combine in definite proportions, and that they combine reciprocally, so as always to neutralize each other. The work of Wenzel attracted little attention, but Richter, in 1792, adopted the views it had developed, pushing the investigations further, and determining by analysis, the numerical quantities of the common bases, and of the acids that would neutralize each other. In the mean time, 1789, an Irish chemist, named Higgins, had advanced the position, that in volatile vitriolic acid, a single ultimate particle of sulphur is united only to a single particle of dephlogisticated air; and that in perfect vitriolic acid, every single particle of sulphur is united to two of dephlogisticated air, being the quantity necessary to saturation.

678. These scattered observations and unconnected researches, like the occasional notices and insulated experiments which preceded the Newtonian era, indicated the approach of the science towards a new generalization, the full development of which was reserved for an illustrious Englishman. In 1803, John Dalton, of Manchester, turned to this subject the attention of a mind remarkable for its power of accomplishing great ends by simple means; for its philosophical moderation, for its acuteness and patience, no less than for its comprehensive grasp and faculty of vivid conception. In the course of an analysis of olefiant gas and of dicarburetted hydrogen, he was struck with the fact, that the carbon in the former was double the quantity contained in the latter. Reasoning from the few facts of the kind which readily presented themselves to his mind, he saw at once the real conditions of chemical combination, and did not hesitate to proclaim the doctrine, that bodies combine by their ultimate particles, and that when more than one combination of two bodies exist, they must be in proportions which are multiples one of the other.

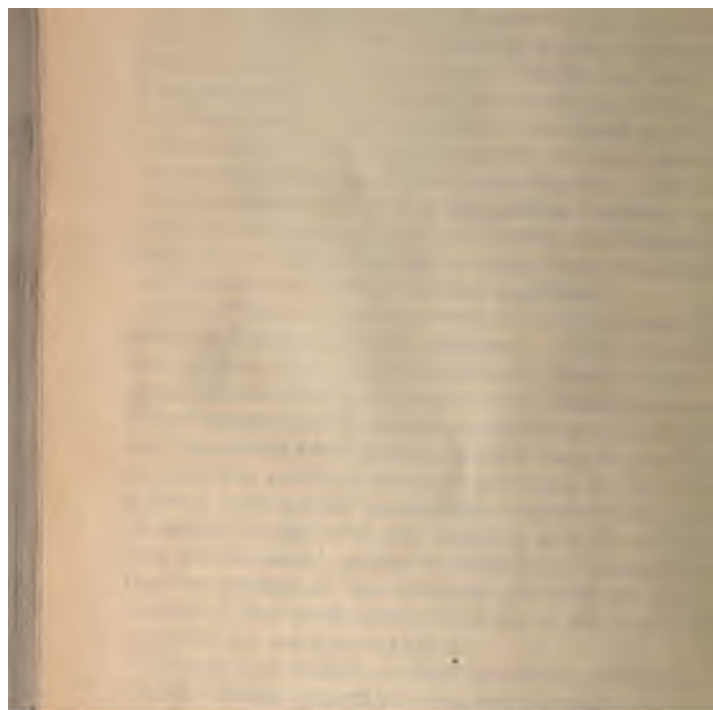
The clearness and simplicity of the notion were irresistible recommendations in its favour; and he pursued the researches to which it led him, with an ardour and success that soon raised it from the rank of a plausible theory, to that of a profound and wide generalization. In 1804, he explained his theory to Dr. Thomas Thomson, of Edinburg, who adopted it in his *Treatise on Chemistry*, published in 1807. Dalton himself gave his own researches to the public in a short system of Chemistry printed in 1808. Dr. Wollaston was one of the earliest advocates of the new views, which he defended in a memoir on the super-acid and sub-acid salts, published in the year last mentioned. The doctrine soon became firmly established over the whole chemical world, and received a striking confirmation from the researches of

Gay Lussac, who discovered that gases unite by volume in simple, definite, multiple proportions, and that the bulk of the resulting compound, when it differs from that of its elements, always bears a simple definite proportion thereto. Dr. Thomson advanced the position that the atomic numbers of all bodies are exact multiples of the atomic weight of hydrogen. This law, if true, would be a simplification of great beauty and convenience; but we are not perhaps able to pronounce positively on the point; for the unavoidable imperfections of our finest analyses, will always leave a slight shade of doubt around the numerical result of every experiment. It seems safer, therefore, to avoid a supposition however convenient, which may lead into error, and strictly to abide by our experiments, leaving their verification and correction to more careful inquirers.

679. The language in which Dalton expressed his doctrine has been much criticised. Wollaston used the phrase *chemical equivalents*. Davy chose to speak of *chemical proportions*, and others have preferred *combining numbers*, as avoiding a theoretical and unproved assumption; but the language of Dalton has the merit of conveying clearly to the mind, a great and simple conception, that reaches to the ultimate principles of the science; and if we admit that the chemical atoms by which bodies combine, may be groups of the ultimate physical atoms, the doubts of the most scrupulous as to the use of his phraseology may be satisfied.

The atomic theory of Dalton was the precursor of the still wider generalization, already alluded to, of Michael Faraday, and the two discoveries may be said to have given to the science a new impulse, more powerful than any which it has felt since the invention of the nomenclature of Lavoisier.









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